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VERIFICATION AND VALIDATION OF BRIGADE/BATTALION SIMULATION (BBS): DATA BASE VERIFICATION, RANDOM NUMBER GENERATION, DETECTION/ACQUISITION, AND MOVEMENT

Fort Leavenworth

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VERIFICATION AND VALIDATION of BRIGADE/BATTALION SIMULATION (BBS): DATA BASE VERIFICATION, RANDOM NUMBER GENERATION, DETECTION/ACQUISITION, AND MOVEMENT

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The Brigade/Battalion Simulation (BBS) model simulates battle at the tactical level of Blue brigade/battalion against Red division/regiment. The model is designed as a command-and-control trainer for the brigade and battalion commanders and their staffs. The purpose of verification and validation (V&V) of BBS is to enhance the overall credibility of the model and to reduce/eliminate any negative training effects. This V&V effort ensures that the methodology in the model is implemented correctly (verification) and that results from the methodology replicate battlefield reality (validation). This document evaluates four sections of the model (data base verification, random number generation, detection/acquisition, and movement).

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ABSTRACT

The Brigade/Battalion Simulation (BBS) model simulates battle at the tactical level of Blue brigade/battalion against Red division/regiment. The model is designed as a command-and-control trainer for the brigade and battalion commanders and their staffs. The purpose of verification and validation (V&V) of BBS is to enhance the overall credibility of the model and to eliminate any negative training effects. This V&V effort ensures that the methodology in the model is implemented correctly (verification) and that results from the methodology replicate battlefield reality (validation). This document evaluates four sections of the model (data base verification, random number generation, detection/acquisition, and movement).

CHAPTER 1

INTRODUCTION

1-1. Introduction. The Brigade/Battalion Simulation (BBS) model is a stochastic model that simulates battle at the operational level of Blue brigade/battalion against Red division/regiment. The model is designed as a command-and-control trainer for the brigade and battalion commanders and their staffs. By maneuvering platoon resolution units, company battle information is obtained and transmitted to the training audience. In addition to the ground battle, BBS represents artillery fire, air support (to include Army air and fixed-wing), air defense, and personnel/logistics to provide a true-to-life training environment.

1-2. Purpose. The purpose of verification and validation (V&V) of BBS is to enhance the overall credibility of the model to eliminate any negative training effects. This effort is to evaluate model methodology and determine that it is analytically sound and appropriate (verification) and that results from this methodology approximate battlefield reality (validation).

1-3. Scope. The entire V&V effort of BBS will be accomplished in phases due to the current fielding schedule and ongoing model development program. This document will report on the following areas: data base verification, random number generation, detection/acquisition, and movement.

1-4. Limitations. An overall limitation is that BBS will operate in an unclassified environment: Therefore, data verification and comparative analysis with any classified combat development (CD) model will be limited. Verification is sufficient when recognized acceptable methodology has been correctly implemented.

CHAPTER 2

DATA BASE VERIFICATION

2-1. Introduction. This chapter describes the verification of the seven data bases that are used to support BBS. Data that is hard-wired within routines and used to support individual modules will be verified during the V&V phase of that module. The data bases described in this chapter are:

a. Initial (Init) data file - Contains the overall unit force structure.

b. Table of Organization and Equipment (TOE) file - Contains generic unit TOE.

c. Equipment data base - Contains the classification and capacities for different equipment.

d. Weapon data base - Contains weapon performance data.

e. Terrain data base - Contains the digitized terrain data base.

f. Terrain file - Contains terrain categories with respective speed and fuel consumption data.

g. Operational State (Opstate) file - Contains opstate categories with respective speed and exposure levels.

2-2. Verification. Verification of the data elements ensures appropriate definitions based upon use in the model. Data elements are reviewed for accuracy based upon available data sources. Verification of BBS was done by identifying the data elements as to the common name, definition, data source, and any transformation needed to derive the data for use in BBS. To ensure completeness of the data base, multiple data sources were used and, therefore, referenced. The actual data files are not provided but are available upon request.

a. The Init data file and the TOE file are both a function of the unit being trained and are constructed/modified prior to the training exercise. Changes to these files are made to meet specific organizations' requirements of the unit commander and, therefore, cannot be verified as part of this effort. The current files have been reviewed to ensure consistency within current doctrine and published field manuals (FM).

(1) The Init data file contains the force organizational structure, initial positions, and initial system strengths of the units. The current data base contains forces for a typical

mechanized battalion for friendly forces and a motorized rifle regiment for threat forces.

(2) The TOE file contains the authorized strengths for the major weapon systems and secondary weapons for generic units, such as a mechanized company. The current TOE file describes various subordinate units of a mechanized battalion and of a motorized rifle regiment. Data sources are standard field manuals for the basic TOE of a friendly unit and FM 100-2-3 for basic TOE of a threat unit.

b. The equipment data base contain the following data elements:

(1) Equipment name - Self-explanatory.

(2) Movement classification - Classified as wheeled, tracked, foot, or air. Used for determining maximum movement speeds for varying operational states and terrain.

(3) Target classification - Used in developing target lists (assessing damage) and in assigning sensors to a system. The current list in the software is:

AA - Antiarmor	AD - Air defense
ADRADAR - Air defense radar	APC - Armored personnel carrier
ARTY - Artillery	B - Truck
C - Engineer	CFRADAR - Counterfire radar
CREW - Crewserved	FGTR - Fighter
HELO - Helicopter	SA - Small arms
SEC - Secondary weapons	S2IR - Infrared sensor
S3CREW - Crewsight	S4TOW - Towsight
S5DRAGON - Dragon sight	S6TANK - TankSight
S7BINOC - Binoculars	S8THREAT - Threat sight
TK - Tank	TRNSP - Transport

(4) Weapon name - The primary weapon for the piece of equipment. The weapon data base contains the weapon's specific characteristics.

(5) Number of crew - Number of soldiers needed to operate the system. Data sources include all referenced Jane's manuals, Special Text (ST) 101-1, and FM 100-2-3.

(6) Maximum passengers - Maximum number of passengers the system can carry in addition to its crew. Data sources include Jane's Armor and Artillery and Jane's Military Vehicles and Ground Support Equipment.

(7) Mean-time-between-failure (MTBF) - Time between system failures. Data sources include United States Army

Training and Doctrine Command (TRADOC) Analysis Command, Fort Leavenworth (TRAC-FLVN), Data Management Division, all referenced Jane's manuals, and interpolation to fill in data voids.

(8) Maximum speed - Normal operating vehicle speed, in kilometers per hour, through flat terrain over secondary roads or aircraft speed at low-level cruising speed. Data sources include Jane's Armor and Artillery, Jane's Military Vehicles and Ground Support Equipment, ST 101-1, and FM 100-2-3.

(9) Fuel rate - Rate of fuel consumption with kilometers per gallon (km/gal) for vehicles and gallons per hour for helicopters and fixed-wing aircraft. A data transformation was used to compute the fuel consumption of helicopters and aircraft. The fuel rate is computed by dividing the mission duration time, obtained in ST 101-1, into the fuel capacity for the craft. Data sources include FM 101-10-1/2, FM 100-2-3, ST 101-1, Jane's Armor and Artillery, and Jane's Military Vehicles and Ground Support Equipment

(10) Fuel capacity - Vehicle fuel tank capacity in gallons. Data sources include Jane's Armor and Artillery, Jane's Military Vehicles and Ground Support Equipment, ST 101-1, and FM 100-2-3.

(11) Load capacity - Carrying capacity of the vehicle in metric tons. Data sources include Jane's Armor and Artillery, Jane's Military Vehicles and Ground Support Equipment, and FM 100-2-3.

(12) Failures - Possible system failures, categorized as engine, electrical, chassis, suspension, communications, and primary weapon.

c. The weapon data base contains data originally provided by TRAC-FLVN, Data Management Division, and updated where noted. The data base contains the following data elements:

(1) Weapon name - Self-explanatory.

(2) Weapon type - Identified as Personal, Direct fire, infrared, Thermal imager, 155mm, 8in, multiple-launched rocket system (MLRS), 105mm, 4_2in, 81mm, 60mm, M43, D_30, M_46, 2S3, BM_21, BM_27, RPU_14, Air1, Air2...Air9. These weapons are further classified as:

A - Light gun
B - Heavy gun
C - Medium mortar
D - Infrared guided weapon
E - Personal weapon
F - Air ordnance weapon
G - Medium gun
H - Light mortar
I - Heavy mortar
J - Thermal imagery weapon
K - Direct fire weapon

(3) Range - Minimum and maximum effective ranges in meters. Data sources include all referenced Jane's manuals, ST 101-1, Field Circular (FC) 101-5-2, and FM 100-2-3.

(4) Ammunition capacity - Basic load capacity in number of rounds to include rounds carried on the system and bulk loads which accompany the fighting system on another carrier (e.g., artillery). Data sources include all referenced Jane's manuals, ST 101-1, FC 101-5-2, and FM 100-2-3.

(5) Bursts per minute and rounds per burst - This combination produces a sustained rate of fire in terms of rounds/minutes. Data sources include all referenced Jane's manuals, ST 101-1, FC 101-5-2, and FM 100-2-3.

(6) Suppressive weight - A factor for each round that contributes to unit suppression. This data element will be reviewed during the V&V of the suppression module. Data source is a data transformation of the United States Army Combat Developments Experimentation Command (USACDEC) experiment FC 029B Suppression Experiment (SUPEX) data used in the Battalion Automated Battle Simulation (BABAS) training model.

(7) Probability of hit (Ph) coefficients - The coefficients for determining the probability of hit. This data element will be reviewed during the V&V of the direct fire module. Data sources include JMEMS, 61 JTCG/ME-80-7-1 document of unclassified munition effects, FC 101-5-2, and TRAC-FLVN, Data Management Division.

(8) Probability of kill (Pk) - Values for probability of kill given a hit for a specific round against various target types. This data element will be reviewed during the V&V of the direct fire module. Data sources include JMEMS, 61 JTCG/ME-80-7-1 document of unclassified munition effects, FC 101-5-2, and TRAC-FLVN, Data Management Division.

(9) Priority - Engagement target priorities that are assigned values from one to five, where one is top priority, and five is no-fire. Data sources include TRAC-FLVN, Data Management Division, FM 17-50, FM 44-1, and military expertise. Target types in the software are:

TK - Tank	CS - Crew
PC - APC	SA - Small arms
AA - Antiarmor	AD - Air defense
AR - Artillery	HE - Helicopters
BV - Trucks	FI - Fighters
CV - Engineers	LO - Bombers
TP - Transport	

d. The digitized terrain data bases that exist for BBS are Fulda, Sinai, Korea, and Fort Irwin. Analysis of the digitized terrain data base is discussed in the movement chapter of this document.

(1) The digitized terrain data is divided into 100-meter squares. Each square is described by elevation and a terrain characteristic.

(2) The source of the Fulda data base was the Defense Mapping Agency (DMA) digitized elevation data and the Bundespost German terrain data compiled by TRAC-FLVN, Data Management Division. The other three areas (Sinai, Korea and Fort Irwin) came from existing BABAS terrain data bases that resided on the Corvis Computer system. Perceptronics converted all terrain data into BBS data structures (see table 5-4).

e. The terrain file data base contains categories that are used to define the terrain types in terms of speeds and factors. Analysis of the terrain file data base is discussed in chapter 5 of this document. The data elements are defined as:

(1) Terrain type - Terrain characteristics that are described in the digitized terrain data base. As used in the software:

- Flat bare
- Flat medium
- Flat dense
- Rolling bare
- Rolling desert
- Rolling medium
- Rolling dense
- Rugged bare
- Rugged medium
- Rugged dense
- Urban
- Road

- Swamp

- Bridge

- Fordable water

- Deep water

(2) Vehicle speed - Maximum speed for vehicles (tracked, wheeled, foot, and airborne) over various terrain types. Data sources for aircraft include ST 101-1 and military expertise.

(3) Fuel factors - Not currently used.

(4) Terrain factors - Used with vehicle speed and climate factor to determine on-road speed. Data source is military judgment.

f. The opstate file data base contains categories that are used to define overall unit operations in terms of speeds, exposure levels, and firepower factors. Analysis of the ground speed data in the opstate file data base is discussed in the movement chapter of this document. Analysis of the exposure levels and firepower factors will be performed during the V&V of the direct fire module. The data elements are defined as:

(1) Vehicle speed - Maximum speed for vehicles (tracked, wheeled, foot, and airborne) while in each opstate. Data sources for aircraft include ST 101-1 and military expertise.

(2) Opstate labels - Names given to the different operations states or missions that the unit could be performing. As used in the software:

(a) Travel-onroad - Unit moving in column formation on road, exposed, with an approximate 100-meter (day) and 50-meter (night) interval between vehicles (5 - 10 meters between dismounted soldiers).

(b) Travel-offroad - Same as Travel-onroad. Expected exposure level is determined by terrain and vegetation. Intervals may vary slightly based on terrain and visibility.

(c) Travel-overwatch - Unit moves basically in a column formation but with a trail overwatch element following at a distance. This overwatch element is capable of returning immediate fire or maneuver against an enemy force.

(d) Bounding-overwatch - Unit moves basically in two elements which alternately move and overwatch the other element. The overwatch element can return immediate fire or maneuver against an enemy force.

(e) Assault-to-objective - Unit in an assault formation takes advantage of available cover and concealment throughout the assault or deliberate attack.

(f) Fight-through - Unit fights through encountered obstacles to continue the attack (bull-through).

(g) Assault-stalled - Unit is in an assault formation but has been attrited or suppressed to a level where the attack stalls. The unit halts, takes advantage of available cover and concealment, and prepares to transition to another opstate.

(h) Pursuit - Unit pursues fleeing enemy force with less regard for cover and concealment. Unit attempts to maintain contact with the enemy.

(i) Ambush - Unit is halted and makes maximum use of cover, concealment, and fields of fire with maximum firepower.

(j) Halt - Unit is halted and takes advantage of available cover and concealment (hasty fighting positions).

(k) Hasty-defense - Unit halts and prepares a hasty defense. Crew-served weapons are emplaced, and positions are prepared as time allows.

(l) Deliberate-defense-I - Unit has at least 50 percent of its primary fighting positions completed. It has little exposure with enhanced firepower due to reduced suppressive impact of incoming fires.

(m) Deliberate-defense-II - Unit is 100 percent dugin. It has minimal exposure with maximum firepower due to reduced suppressive impact of incoming fires.

(n) Delaying-defense - Unit delays, trading space for time. It does not allow itself to become decisively engaged.

(o) Withdrawal-in-contact - Unit is unable to break contact with the enemy. Unit maintains contact with the smallest force required to ensure its secure withdrawal.

(p) Withdrawal-outofcontact - Unit has broken contact with the enemy or withdraws prior to engagement. Speed and manner of withdrawal depend upon enemy situation.

(q) Low-level-flight - Helicopter flight is at a low altitude level where contact with the enemy is unlikely. Flight is at a constant altitude with air speed up to maximum cruise speed.

(r) Contour-flight - Helicopter flight is at the contour of the terrain, or just above vegetation, where contact with the enemy is possible. Flight is at variable altitudes and constant air speed up to maximum cruise speed.

(s) NOE-flight - Helicopter flight is at nap of the earth (NOE), or between existing vegetation, where contact with the enemy is expected. Flight is at variable altitudes and cruise speed to take advantage of masking and vegetation for concealment.

(t) Popup-hover-flight - Helicopter flight is at target and is capable of engaging an enemy force. It takes advantage of masking and vegetation for hovering while allowing other elements of the flight to obtain targeting information.

(3) Fuel factors - Not currently used.

(4) Exposure levels - Exposure factor is associated with each opstate. It is used in resolving direct and indirect conflict. Analysis of the exposure levels will be performed during the V&V of the direct fire module and indirect fire module. Data source is military judgment.

(5) Firepower factor - Percentage of equipment able to engage while in each opstate. Analysis of the firepower factors will be performed during the V&V of the direct fire module. Data source is military judgment.

2-3. Conclusions.

a. The verification of the Init data file and the TOE file is considered complete with the understanding that modifications will occur in preparation for unit training.

b. The verification of the equipment and weapon data base is considered complete with the exception of those specific elements that will be reviewed during subsequent module analysis.

c. The digitized terrain data base, terrain file, and opstate file are further discussed in chapter 5.

2-4. Recommendations. During the course of the data base verification, it was noted that changes to the data base were needed. Data base change relating to such things as basic load capacity, rate of fire, and priority of fires were provided to personnel in the brigade battalion division. It is recommended that these changes be incorporated in the current data bases.

CHAPTER 3

RANDOM NUMBER GENERATION

3-1. Introduction. As a stochastic simulation, BBS makes use of statistical distributions to simulate events that are uncertain or unpredictable. These statistical distributions are modeled through the use of a number stream produced by a pseudorandom number generator. The purpose of the analysis in this chapter is to examine the acceptability of the BBS pseudorandom number generator.

3-2. Random number generator. An acceptable pseudorandom number generator must be able to produce a sequence of numbers between zero and one which simulates the ideal properties of uniform distribution and independence. The pseudorandom number generator implemented in BBS uses the multiplicative congruential methodology and has the form:

$$X_i+1 = (aX_i) \bmod m$$

While this methodology has been shown to be an effective method of generating a number stream with the desired properties, the statistical properties of the stream are highly dependent on the selection of values for a, m, and X_0. The values that BBS uses for these parameters are given in appendix B. The BBS generator was evaluated to determine how well it simulated the desired properties of uniformity and independence.

3-3. Testing. A sample of 500 sequentially generated values was used to test the acceptability of BBS' pseudorandom number generator. Five different tests were performed:

- A Kolmogorov-Smirnov test comparing the sample to a uniform distribution.
- A signs test for location of the median.
- A runs test for runs above and below the median.
- A runs test for ascending and descending runs.
- An autocorrelation test.

The first test addresses the question of uniformity and the last four tests address different problems of independence.

3-4. Conclusion. The tests performed provided no significant evidence upon which to reject the acceptability of the BBS pseudorandom number generator. The specific details of each test as well as sample statistics are provided in appendix B.

3-5. Status. The BBS pseudorandom number generator is acceptable.

CHAPTER 4

DETECTION/ACQUISITION

4-1. Introduction. The purpose of this analysis is to examine the fidelity with which the BBS detection/acquisition module represents the real process of acquisition and to examine the implementation of the conceptual model in the computer program.

4-2. Assumptions.

a. The Night Vision Laboratory detection module is a valid and accepted methodology within the model environment for which it was designed.

b. The line-of-sight (LOS) module of BBS is implemented correctly and represents valid methodology.

4-3. Discussion.

a. Model architecture. Weather and climate states are initialized at the start of the game. These states remain the same until changed by the controller station. The main program calls the procedure UpdateVisibility within the visibility operations module. This procedure processes the visibility status of each unit in the game and then calls the procedure FindVisibleUnits. This procedure discerns between targets that are already in a detected status and those that have not yet been detected. This procedure then calls the procedure LOSBetweenUnits, which first determines the straight-line distance between the designated unit and an undetected unit. The elevation of the designated unit and the undetected unit is then obtained, and the slope for a line drawn between the units is determined. The elevations of points at 50-meter intervals along the line are obtained. The slopes of the line segments connecting the start point to each of these points is then determined and compared to the slope of the original line between the units. If the slope at any given point is greater than the slope between the units, line-of-sight is broken. Otherwise, line-of-sight does exist, and the procedure UnitDetected is called. This procedure is the detection/acquisition module of BBS. It determines the probability of detection based on visibility (both thermal and optical), terrain, target posture, target activity, and the sensor type. A random number is then drawn, and if the drawn number is less than the calculated probability of detection, the target is detected.

b. Data element definitions.

(1) Field of View (FOV) is the portion (angle) of the object scene which is included in the displayed imagery of the imaging system. This value is established by calculating the square root of the area established by the vertical FOV and the horizontal FOV. The dimension of this value is degrees.

(2) Visual Contrast (VCON) is the apparent target-to-background contrast in the visible spectrum. Target types represented are tank and man. Background types represented are open, wooded, and urban terrain.

(3) Thermal Contrast (TCON) is the mean target-to-background temperature difference. Target types represented are tank and man. The background temperature types represented are morning, noon, and night.

(4) Sky-to-Ground Ratio is the ratio of the radiance of the horizon to the inherent radiance of the background.

(5) Atmosphere Attenuation Coefficient (ATTN) accounts for the loss of radiated energy due to atmospheric scattering and absorption. When combined with a specific range, this coefficient determines the fraction of target radiance which reaches the acquiring sensor.

(6) Resolvable Cycles (RC) is the number of cycles which the observer must attain to achieve a specific level of acquisition.

1.0 = Detection (the ability to distinguish that an item in the field of view is of military interest)

1.4 = Orientation (the ability to determine how the target is oriented with respect to the observer)

2.5 = Classification (the ability to distinguish a target by the general type; e.g., tracked, wheeled)

4.0 = Recognition (the ability to discriminate between two targets of similar type; e.g., tank, armored personnel carrier)

6.4 = Identification (the ability to discriminate the exact model of a target; e.g., T-80, T-72)

(7) Target Dimension is the vertical dimension of the visible portion of the target in meters. Target dimension has four categories: man-size target in the open, man-size target partially exposed, tank-size target in the open, tank-size target hull down.

(8) System Magnification (AMAG) is the magnification by the sensor system for the particular FOV utilized.

(9) Sensors are the acquisition devices that are modeled in BBS. These sensors are eyes, binoculars, individual starlight scope, crew-served starlight scope, Dragon thermal sight, tank thermal sight, and enemy starlight scope.

(10) Light Levels are the seven levels of illumination that are played in BBS.

100	foot candles =	overcast day / clear day
10	foot candles =	heavily overcast day
1	foot candles =	sunset overcast day
0.1	foot candles =	15 minutes after sunset
0.01	foot candles =	30 minutes after sunset
0.001	foot candles =	moonlight clear night
0.0001	foot candles =	moonless clear night

(11) Scan Rate is the average time required by an observer to search one device FOV.

(12) Detection Time is the time interval specified for the game update cycle and is the time interval for which a specific probability of detection is calculated.

(13) Scan Elevation and Scan Azimuth are the values that define the search area for the acquisition devices.

c. Verification. The methodology used in the analysis to verify the detection acquisition module incorporates three techniques. These techniques are methodology review, structured walk-through, and a check run.

(1) Methodology review, when considered within the verification process, involves a brief review of the implemented methodology. This review is conducted to provide the necessary background for the rest of the verification process.

(a) The detection/acquisition module in BBS is essentially the 1977 U.S. Army Night Vision Laboratory's (NVL) detection/acquisition module used in their night combat model. The model is composed of three primary submodels: the static detection model, the FOV search model, and the search model. A detailed description of these submodels can be found in TR 6-77, Simulating Combat Under Degraded Visibility.

(b) This methodology enjoys a general acceptance as valid within the conditional environment for which it was designed. The conditional aspects of this model include stationary targets, stationary observers, and a single target in the FOV. Combat operations in general, and specifically the

tactical environments that BBS is expected to simulate, are not limited to this conditional environment. It is necessary to extend the methodology to account for these aspects of combat.

(c) BBS extends the NVL detection/acquisition module to the moving target by reducing the search area of the observer when the target is moving. The search area is reduced from a 20-degree vertical scan and a 30-degree horizontal scan to a 10-degree vertical scan and a 9-degree horizontal scan. This adjustment was originally proposed based on the following assumption: an observer would, with certainty, detect a moving target and would switch his sensing device to a narrow field of view. The effect of this reduction in the search area is an increase in the probability of detection within one time cycle and a reduction in the time to detect. No other extensions were made to account for a moving observer or a multitarget environment.

(d) The validity of the application of this model with the single extension is considered in the validation section of this report.

(2) The structured walk-through analysis involved a line-by-line evaluation of the transfer of the detection/acquisition module from the code used by the NVL to the code used in BBS. The NVL version uses FORTRAN while the BBS version is written in Modula II. This comparison revealed one error in the conversion of the code. In the subsection of the procedure Eyes that covers case 1 (light level 1), the first "End" statement is misplaced. This causes the code to misrepresent the original model and consequently calculate incorrect probabilities of detection and times to detect. This error is corrected by moving the "End" statement to the end of the case 1 subsection (Brigade/Battalion Simulation Division (BBSD) notified).

(a) An inaccuracy exists in the manner in which the program assigns sensors to various weapon systems. The code currently assigns sensors based on the target classification of the weapon system. Weapon systems of significantly disparate sensor capabilities are grouped together into the same target categories. This grouping is consistent when considering the target characteristics of the weapon systems but produces problems when other characteristics are important. A specific example illustrates the implications of the current coding. M113s, infantry fighting vehicles (IFV), and improved tow vehicles (ITV) are target classified as APC (armored personnel carrier). This classification is then used to assign sensors to each weapon system. The sensor associated with an APC is a Dragon thermal sight. The program assigns a Dragon thermal sight to the IFV and the ITV. This assignment significantly misrepresents the true sensor capabilities of the IFV and the ITV and unrealistically reduces the effectiveness of these weapon

systems. This problem can be solved by assigning sensor capabilities based on data in the TOE data table. This data table specifically links weapon systems with the appropriate sensor (BBSD notified).

(b) Some of the assignments of terrain categories (e.g., rolling dense, flat bare, etc.) to background categories (open, wooded, and urban) for use in selection of the visual contrast parameter are questionable. Rolling desert is not assigned a background category, bridges are assigned wooded, roads are assigned urban, and deep water is assigned wooded. These inaccuracies result in improper selection of VCON values and improper probabilities of detection (see table C-1).

(3) A check run of the BBS detection/acquisition module was conducted to verify that the model produced the same results as the NVL model under the same input conditions. The BBS results were identical to those reported in figure A-3 of the NVL report with a single exception. The exception occurs with the Dragon sight at a range of 3,500 meters. While the NVL results for the probability that the searcher will ever find the target, given the target is in its field of view (P(inf)) drop to zero, the BBS results continue an exponential decline and P(inf) is 0.5367. Consequently, the results for the mean search time (TBar) and the probability that detection will occur within 30 seconds (P(30)) differ also. Discussions with one of the authors of the 1977 NVL report and review of the code in the report did not provide a specific reason for Dragon sight performance dropping to zero. Hand calculations of the code reported in the 1977 NVL report produce the results achieved with BBS. A mistake in reporting or other steps not specifically detailed in the report may have been the reason for the Dragon value reported by NVL for 3,500 meters. This deviation is not considered a significant concern to the correct operation of the model since range restrictions in the model do not allow the Dragon to be employed at this range.

d. Validation. While validation of already validated methodology is not required (Quality Control Board 22, July 1988), examination of the application of the methodology and extensions to the methodology are a concern. The analysis consists of a methodology review, a sensitivity analysis, and data validation.

(1) Methodology review in the context of the validation process consists of reviewing the conceptual methodology to ensure it represents the real system and is appropriate to meet model requirements.

(a) As indicated previously, the BBS detection/ acquisition module implements the 1977 NVL detection/acquisition module with the addition of one extension. The extension implemented in BBS (a reduction of the search area for moving

targets) is a dated ad hoc methodology. The Model Support Directorate (MSD) at TRAC_FLVN devised this ad hoc technique to fill a recognized void in the NVL methodology when it was used in a moving target environment. This method was developed for use with a two-step acquisition process: detection and, given detection, a second "look" for acquisition. NVL, the Army Materiel Systems Analysis Agency (AMSAA), and MSD currently support the use of a different methodology. The replacement methodology consists of halving the resolvable cycle requirements for acquiring moving targets and is appropriate for use in the one-step acquisition process currently used in BBS.

(b) No extensions of the NVL model have been implemented to expand the model to the moving observer or the multiple target environment. Methods to account for these conditions are currently available. The moving observer condition is captured through the use of a degradation factor. It is reasonable, intuitively appealing, and supported by military literature to assume that it is harder to acquire targets while the observer is moving than while stationary. The values associated with the degradation factor are subjective. Empirical support for specific values was not found. The multiple target environment has been roughly accounted for by dividing the TBar produced by the model by the expected number of targets in the FOV.

(c) An extension to cover acquisition under the condition of suppressive fire has been implemented in BBS. Verification and validation of suppressive fire will be addressed in a separate analysis of this module.

(d) False targets are not played in BBS. Test data from the Smoke 5-B test indicate that the false alarm rate (the false detection probabilities) is quite low. The exclusion of false targets, therefore, seems reasonable and is not expected to affect battle outcome.

(e) The NVL detection/acquisition module was designed to support the easy integration of new sensor systems. The model was initially oriented toward the examination of combat operations under degraded visibility conditions. Consequently, not all types of sensors are represented in the 1977 NVL model. BBS only implements those sights implemented in the 1977 NVL model. Tank, TOW, and Dragon optical sights, for example, are not represented in BBS. These sights are a significant aspect of the BBS environment.

(f) Enemy thermal capabilities are not represented in the detection/acquisition model. This is appropriate because the Soviet's currently have not fielded this capability. The Soviet approach to night operations is to make them into day operations through the use of extensive illumination. Thus, the modeling of battlefield illumination is appropriate. BBS currently includes

illumination rounds but the use of this munition has no effect on detection/acquisition process. One source of methodology to model battlefield illumination is the illumination module of the NVL model. Figure C-1 illustrates the disparity between blue and red capabilities when battlefield illumination is not modeled. While blue thermal sights provide an inherent advantage in night operations, red's inability to use battlefield illumination inappropriately exaggerates this advantage.

(2) Sensitivity analysis is a technique in which the values of the input parameters are changed, and the effect of these changes on model output is observed. The effects of the changes in the model should be the same as those observed or expected in the real system. The baseline parameter values for this analysis are provided in table C-2. The baseline represents a target scenario of a hull-down tank in open terrain under daylight conditions. Other baseline values represent values currently implemented in BBS.

(a) The number of resolvable cycles required for acquisition was varied through four values: 1.0, 2.0, 2.5, and 4.0. The effects of these changes on P(inf) and P(15) were as expected. As the requirements for acquisition became more stringent, the probabilities of detection decreased (figures C-2 and C-3). The distribution of times to detect (TBar) were unchanged across the value changes of RC.

(b) The effect of the attenuation coefficient for the tank thermal sight was examined at the values of 0.5, 0.168, and 0.540. The output curves for P(inf), P(15), and TBar were identical for coefficient values of 0.5 and 0.168. Comparison of the respective output curves for attenuation coefficients of 0.168 and 0.540 began to diverge at a range of 1,750 (figures C-4 and C-5). As expected the probabilities of detection decreased for a higher attenuation coefficient. TBar increases with a higher attenuation coefficient, and is consistent with expectations (figure C-6).

(c) The Scan Rate was varied from 1.7 seconds to 3.4 seconds. There were no changes to the values for P(inf) and the values for TBar doubled. The curve for P(15) at a scan rate of 3.4 begins at about half the value of the curve of P(15) at a Scan Rate of 1.7. The curves begin to converge as the range gets greater (figure C-7). These results are consistent with the expectation that the significance of Scan Rate as a determining factor for probability of detection decreases over range.

(d) TCON was varied from two degrees to eight degrees by one-degree increments. P(inf), P(15), and TBar for the TOW thermal sight and the Dragon thermal sight varied over the complete range of TCON values (figures C-8 through C-13). The tank thermal sight was not sensitive to changes above a four-

degree thermal contrast (figures C-14 through C-16). The range of sensitivity to TCON for more powerful sensors is smaller than for less powerful sensors. Thus, the results are consistent with reality. As the thermal contrast was increased, the probabilities of detection increased, and the time to detection decreased as expected. While absolute changes over the range of TCON values are small, the relative change ranges from 4 percent to 14.8 percent. This sensitivity impacts on the level of aggregation that may be used in developing the thermal contrast values and will be addressed in the data validation section. Optical sights, appropriately, are not sensitive to changes in TCON.

(e) Analysis of the effects of Visual Contrast was conducted after correcting the error identified in paragraph 4-3c(2). The VCON value was halved and doubled for this examination. All optical sensors showed moderate sensitivity to changes in VCON. As VCON was increased, the probabilities of detection increased, and TBar decreased (figures C-17 through C-21). The thermal sensors, as expected, were not sensitive to changes in VCON.

(f) Analysis of the Sky-to-Ground Ratio was conducted after correcting the error identified in paragraph 4-3c(2). The impact of Sky-to-Ground Ratio was examined for both day and night conditions. The Sky-to-Ground Ratio values used were 1, 3, 5, 8, and 10. All optical sensors, with the exception of binoculars, showed moderate sensitivity to changes in Sky-to-Ground Ratio for both day and night conditions. Binoculars showed high sensitivity. The day run results are shown in figures C-22 through C-26. Increasing the Sky-to-Ground Ratio decreased the probability of detection and increased the time to detect. This is consistent with real conditions. Thermal sensors, appropriately, were not sensitive to changes in the Sky-to-Ground Ratio.

(3) For data validity, the primary source of parameter values is the 1977 NVL Study. FOV, Sky-to-Ground Ratio, Target Dimension, AMAG, and Scan Rate were all obtained from this source. TCON values were obtained from a more recent source, The Target Acquisition Handbook, Part I, Discrete Sensor Performance, September, 1985. The source of VCON values is unknown. In general, the values used for these parameters were found to be acceptable, with exceptions discussed below.

(a) A single value for Sky-to-Ground Ratio is used in BBS. The probabilities of detection are moderately to highly sensitive to changes in the Sky-to-Ground Ratio. This sensitivity reflects a real phenomenon illustrated by the expression "attacking out of the sun." The reality of the phenomenon, the sensitivity of the detection probabilities to

Sky-to-Ground Ratio, and the need to include additional optical sensors argue for multiple value modeling of this parameter.

(b) The values for TCON used in BBS are an average of thermal contrast values for each season at locations in Europe and the Mideast. The model's low sensitivity to changes in TCON, coupled with TCON's relatively low sensitivity to location, support the aggregation of TCON. TCON is more sensitive to time of day effects, and BBS, appropriately, does not aggregate across time of day.

(c) The source of the values for VCON in BBS is unknown. The NVL study used a single value of 20 percent for all visual contrasts. The Target Acquisition Handbook provides data that show a large variation of contrast signatures based on combinations of target coloring (camouflage, green, sand, etc.) and background classification (green foliage, dead grass, sand, etc.). For example, the contrast for a tank painted green varies from -.03 against a green foliage background to -.61 against a dirt road background. It is unrealistic and unnecessary to represent the many combinations of target color and background. However, the appropriate level of aggregation is a concern. The current VCON combinations of target color and background, when compared to The Target Acquisition Handbook data and AMSAA guidance, appear appropriate for representations within European scenarios. Terrain characteristics of certain other areas of operation (e.g., Middle East) may require other combinations of color and background. The values currently used in BBS for the combinations represented are reasonable aggregated representations of available data with two exceptions. Tank contrasts are higher than man contrasts for every combination presented in The Target Acquisition Handbook. BBS, however, uses a higher contrast for a man in the open than for a tank in the open. The second exception is not an error but a lack of data by which to evaluate BBS values for contrast in urban environments. The inclusion of VCON values in the code makes it difficult to update the model either for changes in geographical location or as better data become available.

4-4. Conclusions. The implementation of the NVL methodology in BBS has significantly improved the model's representation of combat.

a. The verification of the BBS detection/acquisition module identified an error in translating the code from the NVL model to BBS, an error in the assignment of sensors to weapon systems, and an error in the assignment of terrain categories to visual contrast background categories. These errors are unacceptable in terms of verification of the detection/acquisition module.

b. The 1977 NVL detection/acquisition module was developed for certain conditions. BBS simulates a far more encompassing view of combat than that for which the NVL model was developed. The application of the NVL model in BBS is inappropriate without adequate extensions accommodating the extended environment that BBS is intended to simulate. Currently the BBS detection/acquisition model lacks adequate extensions. These inadequacies include a lack of representation of battlefield illumination's effect on detection/acquisition, a lack of representation of certain significant friendly sensors, and no correction for moving observers or a multiple target environment.

c. The representation of Sky-to-Ground Ratio as a single-value parameter is questionable based on the sensitivity of the probabilities of detections to changes in this parameter.

d. The current level of aggregation of the TCON parameter is appropriate and provides a realistic representation of the physical phenomena.

e. The visual contrast parameter in BBS is appropriately represented for European scenarios except the values used for VCON of a man in the open and of a tank in the open are reversed. Vigilance should be maintained for better data for this parameter, particularly concerning urban environments. The hardwiring of this parameter does not support easy transition to other areas of operation or the integration of better data.

f. The exclusion of false target representation in BBS does not detract from the model's ability to sufficiently represent the combat detection/acquisition process.

4-5. <u>Recommendations</u>. The following recommendations are based on the expectation of at least a moderate negative training impact if not implemented. Many of the recommendations leave the method of implementation open. This flexibility will allow full consideration of resource constraints, time considerations, near-future methodology and data advances in the implementation decision.

a. These recommendations pertain to the verification process.

(1) Correct the coding error in the procedure Eyes (Paragraph 4-3c(2)).

(2) Adjust the program to assign sensors based on the TOE data table rather than the Target Classification data table (Paragraph 4-3c(2)(a)).

(3) Fix the assignment of terrain categories to background categories and document the need to review and update these assignments when changes to the terrain data base are made (Paragraph 4-3c(2)(b)).

b. These recommendations pertain to the validation process.

(1) Update the method of accounting for moving targets to currently supported methodology (Paragraph 4-3d(1)(a)).

(2) Extend the model to account for moving observers and multiple targets (Para. 4-3d(1)(b)).

(3) Add representation of battlefield illumination, and representation of significant friendly sights that are currently not represented (Para. 4-3d(1)(e) and 4-3d(1)(f)).

(4) Develop the Sky-Ground Ratio as a multi-valued parameter rather than a single-valued parameter (Paragraph 4-3d(3)(a)).

(5) Correct the VCON values for a man in the open and a tank in the open. Limit BBS scenarios to Europe until VCON is extended to represent color/background combinations that dominate other areas of operation (Paragraph 4-3d(3)(c)).

4-6. Status. Verification and validation is ongoing. The above recommendations are being considered by BBSD for implementation. Module reevaluation will take place after decisions and actions regarding these recommendations have occurred.

CHAPTER 5

MOVEMENT

5-1. Introduction. This chapter describes the current movement methodology in BBS and the associated V&V analysis.

5-2. Assumptions. The Condensed Army Mobility Model System (CAMMS) from Waterways Experimental Station (WES) is an approved model for mobility analysis.

5-3. Discussion.

a. Model architecture. Movement is initiated with an order given by an interactor at a work station to a specific unit on the battlefield. The order is composed of location, operational state (opstate), and commander's desired speed. Overall unit speed is based upon commander's desired speed, base unit speed, terrain, climate conditions, opstate, and suppression. Tables 5-1 and 5-2 show the data tables that are used. Table 5-3 consists of a portion of the weather data menu used by the interactor during an exercise. The actual unit speed is determined to be the minimum of four speed values (base unit speed, commander's desired speed, environmental speed (terrain and climate) and opstate speed). Updating the unit location is based upon the speed and direction of travel that is computed at a 15 second interval.

(1) Base unit speed is determined to be the speed of the slowest vehicle in the unit's TOE from the equipment data base. The vehicle speed is considered to be "foot" when the unit is dismounted.

(2) Environmental speed (Env_Speed) is computed from the speed from the terrain data file and a climate factor (Climate_Mvmt_Factor) from the weather data base. This environmental speed is then modified by a terrain factor (Terrain_Factor) while moving "on road" (defined when a unit is placed in a Travel-onroad opstate). As extracted from the software:

Env_Speed = Terrain_Speed_Table * Climate_Mvmt_Factor

Temp_Speed = Env_Speed * Terrain_Factor

where: Terrain_Speed_Table is a function of terrain type and vehicle type (tracked, wheeled, and foot)

Climate_Mvmt_Factor is a function of vehicle type

Terrain_Factor is a function of terrain type.

(3) Opstate speed (Op_Speed) is computed from the opstate speed table and a suppression level for the unit. The suppression level is a result from the suppression module which is not verified and validated at this time. As extracted from the software:

```
Op_Speed = Opstate_Speed_Table * (1.0 - Suppres_Lvl)
```

where: Opstate_Speed_Table is a function of unit opstate and vehicle type.

Suppres_Lvl is the percent of suppression a unit is receiving.

(4) The overall unit speed is then computed to be the minimum of the base unit speed, the commander's desired speed, the modified environmental speed, and the opstate speed. As extracted from the software:

```
SPEED = MIN(Base_Unit_Speed, Commander_Speed, Temp_Speed, Op_Speed)
```

Table 5-1. Terrain data

Terrain type	Airborne speed	Vehicle speeds (kph) tracked	wheeled	foot	Terrain label	Terrain factor
T1	300.0	50.0	70.0	8.0	Flat bare	1.0
T2	270.0	20.0	20.0	4.0	Flat medium	2.0
T3	210.0	8.0	5.0	4.0	Flat dense	6.0
T4	294.0	35.0	35.0	7.0	Rolling bare	1.7
T5	250.0	20.0	10.0	1.0	Rolling desert	3.0
T6	240.0	15.0	10.0	4.0	Rolling medium	2.0
T7	180.0	7.0	4.0	3.0	Rolling dense	5.0
T8	195.0	12.0	10.0	3.0	Rugged bare	5.0
T9	150.0	8.0	5.0	3.0	Rugged medium	4.0
T10	120.0	5.0	3.0	2.0	Rugged dense	5.0
T11	240.0	10.0	25.0	3.0	Urban	1.0
T12	180.0	50.0	70.0	8.0	Road	1.0
T13	120.0	5.0	3.0	1.0	Swamp	5.0
T14	90.0	20.0	20.0	8.0	Bridge	1.0
T15	300.0	8.0	2.0	1.0	Fordable water	1.0
T16	90.0	5.1	3.1	3.1	Deep water	1.0

Table 5-2. Opstate data

Opstate	Airborne speed	Vehicle speeds (kph) tracked	wheeled	foot	Opstate label
OS1	120.0	50.0	70.0	8.0	Travel-onroad
OS2	120.0	20.0	20.0	8.0	Travel-offroad
OS3	120.0	8.0	8.0	6.0	Travel-overwatch
OS4	120.0	5.0	4.0	4.0	Bounding-overwatch
OS5	120.0	4.0	4.0	4.0	Assault-to-objective
OS6	120.0	5.0	5.0	5.0	Fight-through
OS7	120.0	1.0	1.0	1.0	Assault-stalled
OS8	120.0	20.0	20.0	8.0	Pursuit
OS9	1.0	1.0	1.0	1.0	Ambush
OS10	1.0	1.0	1.0	1.0	Halt
OS11	1.0	1.0	1.0	1.0	Hasty-defense
OS12	1.0	1.0	1.0	1.0	Deliberate-defense-I
OS13	1.0	1.0	1.0	1.0	Deliberate-defense-II
OS14	120.0	8.0	8.0	6.0	Delaying-defense
OS15	120.0	8.0	8.0	6.0	Withdraw-in-contact
OS16	120.0	20.0	20.0	6.0	Withdraw-outofcontact
OS17	320.0	0.0	0.0	0.0	Low-level-flight
OS18	210.0	0.0	0.0	0.0	Contour-flight
OS19	65.0	0.0	0.0	0.0	NOE-flight
OS20	1.0	0.0	0.0	0.0	Popup-hover-flight

Table 5-3. Climate factors

Vehicle type	Climate mvmt factor
Tracked	1.0
Wheeled	1.0
Foot	1.0

b. Verification. This is the process of review to ensure that the movement methodology is implemented correctly as designed. The methodology used to verify the movement methodology in BBS was to conduct a methodology review, a structured walk-through of the code, and a data review.

(1) The methodology review involved reviewing available documentation to determine the conceptual approach to the movement methodology and consult with technical experts if the methodology is reasonable. The concept of determining the base unit speed on the slowest moving vehicle in the unit and the use of "foot" speed for the base unit speed when the unit is dismounted are both acceptable methods. The process of computing the speed based upon the minimum of terrain speed and a user-entered operation speed is the current technique used in the combat development model Combined Arms and Support Task Force Evaluation Model (CASTFOREM).

(2) A structured walk-through of the code proved to be consistent with the intended methodology and available documentation. The code for the update of unit locations was not reviewed, but testing was performed to issue unit orders to specific locations and to verify that the unit did move to the correct location, both on the video display and in model output.

(3) A data review of all data requirements needed to support the methodology, to include data sources, was performed. Data requirements fall into four categories: digitized terrain, commander's desired speed and climate factors, unit performance of the vehicle speeds, and terrain/opstate table speed with terrain factor.

(a) The format and source of the digitized terrain data bases were discussed in chapter 2. Although a verification of the digitized terrain data bases was not part of this effort, background and current status is discussed. As mentioned previously the source for the digitized terrain data bases was in BABAS format data that originally contained only vegetation characteristics. The BABAS model used this terrain data for computing line of sight and had gamer interaction to determine unit movement rates. The current BBS digitized terrain data base was expanded to include a combination of vegetation and surface slope characteristics. Table 5-4 shows the conversion that was used to translate BABAS data format into BBS data format. The mapping of BABAS format data loads vegetation data without consideration of surface slope features.

1. A review of the terrain data resulted in BABAS-type "7-dry land" in level areas and in steeply sloped areas, both being identified as the same BBS-type "T8-rugged bare". This would tend to constrain vehicles moving in flat terrain to the speed at which they would move when in rugged terrain.

2. The BBS digitized terrain data base was then further expanded to include roads, bridges, and rivers by modifying the data base to the schema described in table 5-5. This data modifying process was done manually for the Fulda data base only. A random sampling of the 100-meter cells from the Fulda data base

were visually compared with the video displays in BBS. The video display in BBS is a direct representation of government maps at resolutions from 1:50,000 to 1:500,000. The results of the comparisons provided no evidence of incorrect entry. Software written by Perceptronics was developed as an aide in changing the digitized terrain data base manually. The other digitized data bases (Korea, Fort Irwin, and Sinai) have not been modified and still contain the original BABAS to BBS terrain conversion schema without the conversions described in table 5-5.

Table 5-4. BABAS to BBS terrain conversion

BABAS	BBS
0 - Undefined	T0 - Undefined
1 - Large city	T12 - Urban
2 - Small city	T12 - Urban
3 - Coniferous forest	T7 - Rolling dense
4 - Mixed forest	T7 - Rolling dense
5 - Deciduous forest	T7 - Rolling dense
6 - Heath/bush	T6 - Rolling medium
7 - Dry land	T8 - Rugged bare
8 - Marsh	T13 - Swamp
9 - Fresh water	T15 - Fordable water
10 - Salt water	T16 - Deep water

Table 5-5. Manual BBS terrain conversion

	Old type	New type
T11	Urban medium	Urban
T12	Urban dense	Road
T13	Swamp medium	Swamp
T14	Swamp dense	Bridge
T15	Fordable water	Fordable water
T16	Impassible	DeepWater

(b) The commander's desired speed is a data input from an interactor during a training session. The climate factor is a function of data input from an interactor as part of the overall weather menu. The weather parameters that affect the climate factor are precipitation, cloud cover, and ambient light. This type of data is considered scenario input and will not be verified.

(c) Vehicle speed was verified by reviewing field manuals and Jane's publications.

(d) The speed tables (terrain and opstate) and the terrain factor are inherently part of the table look-up movement methodology. Average rates of march, shown in figure D-1, appendix D, were extracted from FM 7-20, The Infantry Battalion, 24 December 1984. Care should be taken in using these rates as they are associated with battalion movements of company-sized march units. Speeds for tracked and wheeled vehicles are discussed in the validation section.

c. Validation. This is the process to ensure that the model replicates battlefield reality. The methodology to validate the movement module was a comparison of CAMMS and BBS. This analysis consists of comparing the vehicle movement rates as computed in CAMMS and in BBS and identifying the effects of different terrain conditions on vehicle movement rates.

(1) To compare vehicle movement rates in CAMMS and BBS, similar terrain in both models was identified, and speeds were computed for the same vehicles within the same scenario. Similar, rather than identical, terrain was used because there was no common terrain data between the models.

(a) The current digitized terrain data bases available in CAMMS are the North German Plains and Korea. These areas are not in the BBS terrain. Although it appears the Korea data base is common to both models, there is no identical terrain area in both CAMMS and BBS. A terrain analysis was performed to identify 100-meter cells in the CAMMS North German Plains and BABAS format data files supplied by TRAC-FLVN, Data Management Division, that were used to generate the BBS digitized terrain data base. The analysis consisted of identifying cells in CAMMS with appropriate 1:50,000 government maps and obtaining the BABAS data elements from the data files of the same area. Terrain cells were identified as forest, heath/bush, and dry land by the map legend, and then corresponding BBS terrain characteristics were identified using table 5-4 (rolling medium, rolling dense and rugged bare). As previously indicated, the BBS terrain converison does not account for slope. This conversion was considered in selecting terrain cells for the comparison. It also required a subsequent sensitivity analysis.

(b) All vehicles in BBS are classified as tracked or wheeled. CAMMS contains the following vehicles in the data base:

M1A1 - Main tank
M113A1 - Armored personnel carrier
M2 - Infantry fighting vehicle
M35A2 - 2 1/2-Ton cargo truck
M977 - 10-Ton cargo truck (HEMTT)
M998 - 1/2-Ton cargo truck (HMMWV)
LACH - Dozier
LVS - (Dragon wagon)

The M1A1 and the M977 were chosen for analysis because they are the widest and heaviest vehicles in their respective class (tracked and wheeled).

(c) CAMMS predicts off-road vehicle movement rates based upon a user defined scenario. This scenario describes the weather conditions in terms of rainfall, time of year, and surface conditions (normal, slippery, or snow-covered). In predicting movement rates, six characteristics are considered:

Soil - Type and strength
Slope - Percent slope
Surface roughness - Variations in ground surface profile
Vegetation - Spacing of stems (trees) in terms of diameter
Visibility - Distance the vehicle operator could see over vegetation height
Obstacles - Linear obstacles

(d) Movement rates in different opstates are very subjective and depend on the overall unit objective and enemy activity in the area. Combat models such as CASTFOREM allow for unit orders to determine movement rate as defined by the scenario and not computed by the model, while JANUS(T) does not consider opstate when computing unit movement.

(e) BBS predicts movement rates as a result of the table look-up methodology. To maintain a consistent scenario with CAMMS, BBS movement rates did not contain climate or suppression factors. It was also assumed the unit's slowest moving vehicle was an M1A1 or an M977.

1. The computed movement rate would never be obtained by the current methodology when it is larger than entries for terrain data (FlatBare or Road) or opstate data (Travel-OnRoad); e.g., maximum road speed for an M1A1 tank is 73 kph. In a scenario of a tracked vehicle moving on road in an opstate of Travel-OnRoad with no suppression, BBS would determine the speed to be 50 kph given the current data tables.

2. The current methodology would allow tracked vehicles, limited by the actual maximum speed, to move at the same speed over the same terrain while in the same opstate; e.g., an M1A1 tank (maximum speed of 73 kph) and an M88 recovery vehicle (maximum speed of 48 kph) will both move, while in a Travel-OffRoad opstate, at 20 kph.

3. The current methodology would allow a unit of tracked vehicles to move at the same rate in different types of terrain while in the same opstate; e.g., an M2 infantry fighting vehicle (IFV) will move at 4 kph while in an Assault-to-Objective opstate in FlatBare terrain as well as RuggedDense terrain.)

(f) Runs of the CAMMS model were made to predict vehicle speeds using the III Corps North German Plains data base. The scenario chosen was average precipitation and normal surface conditions in both February (winter) and July (summer). Within tables D-1 through D-12, Appendix D, three different combinations of terrain characteristics affecting speed are:

1 SSRV - Soil, Slope, surface Roughness and Vegetation: main characteristics affecting speed according to WES personnel.

2 SRV - Slope, surface Roughness and Vegetation: implied characteristics representing current BBS terrain codes.

3 V - Vegetation only: direct comparison to BBS terrain as determined by the terrain conversion schema.

(g) The CAMMS and comparitive BBS table look-up results are found in tables D-1 through D-12, appendix D, using the following key for the terrain cases:

Terrain Case	CAMMS	BBS
1	Dry land	Rugged bare/flat bare
2	Heath/meadow	Rolling medium
3	Forest	Rolling dense

1. Analysis of the data shows that speeds in the SRV and V characteristics in terrain cases 1 and 2 are higher in CAMMS than in BBS. This analysis would indicate that speeds in both of the BBS speed tables should be increased. In terrain case 1, the BBS results are closer to the CAMMS results when using only the terrain speed table with a correct terrain conversion.

2. The results in terrain case 3 are reversed. Speeds are larger in BBS than in CAMMS. The CAMMS model does not allow for any movement in a forested area. A map review indicates

there are small trails wide enough for vehicles to move. It would seem reasonable there would be some movement in that area, but movement rates in BBS could not be validated.

(2) A sensitivity analysis of the CAMMS runs shows the differences of movement speeds with respect to different terrain considerations. Figures D-2 through D-10, appendix D, use the same CAMMS terrain characteristic definitions that were stated above and show general movement trends over a larger area of terrain (6 x 4 km) than results from the 100-meter cells used to obtain the data for tables D-1 through D-12, appendix D.

(a) Analysis of an M1A1 tank (figures D-2 through D-4, appendix D) and an M977 truck (figures D-7 through D-9, appendix D) in July shows that soil is a major factor in considering speed.

(b) Analysis of vehicle speed between July (summer) and February (winter) for both M1A1 tank and M977 truck shows less of an overall difference.

(c) The review of the figures D-2 through D-10, appendix D, confirms results from the speeds computed from the individual 100-meter cells from tables D-1 through D-12, appendix D.

5-4. Conclusions. From the above analysis it is determined that there are problems with the results produced from the movement module.

a. The use of BABAS vegetation classification format data, without including elevation data to build the digitized terrain data base, is inappropriate for use in BBS with the current terrain descriptions in table 5-1.

b. The manual data changes to the Fulda digitized terrain data base as identified in table 5-5 were entered correctly, but the digitized terrain data bases, to include the Fulda, are not verified.

c. There are differences in movement rates, considering seasonal weather factors and soil conditions, but not of a significance to implement at the resolution of this model.

d. The overall table look-up methodology has been implemented according to current available documentation. Considering other currently implemented movement techniques, it is a acceptable approach for computing movement rates based upon physical terrain limitations resulting from speeds in the terrain speed table.

e. The entries, with the exception of Travel-OnRoad, in the opstate speed data table are subjective and cannot be validated.

The entries may actually be redundant and somewhat confusing since the commander's desired speed is also used in determining final speed for the unit.

5-5. Recommendations.

a. Generate new terrain data bases from DMA data or other appropriate data sources. Definitions should be developed for the terrain types to include the existing terrain roughness (mobility factors). An alternative is to utilize the current digitized terrain data bases and manually upgrade the data base to include terrain roughness. A formal V&V analysis on this manually upgraded terrain data base would be needed.

b. Use results from the CAMMS model to fill out and complete the vehicle speed data elements in the terrain speed table, table 5-1, where appropriate.

c. Remove the duplication of the opstate speed and the commander's desired speed in computing the overall unit speed.

5-6. Status. Verification and validation is ongoing. Considering that this module is under current revision, the above conclusions and recommendations should be considered during current work effort and the module reevaluated when the module is more stable.

CHAPTER 6

GENERAL RECOMMENDATIONS

The following recommendations are presented to enhance the overall aspect of model maintenance and fielding but should not affect the normal functionality of BBS.

a. Data should not be hardwired in code, but read as input from data files for more flexibility. This coding standard would result in an easier transition to different data bases and data upgrades without recompiling the model.

b. When possible, the interactor menus should reference data as was read into the model from the data files rather than having it hardwired in the code. If the data file is changed, then code also has to be changed.

APPENDIX A

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APPENDIX B

RANDOM NUMBER GENERATOR TESTS

B-1. <u>BBS pseudorandom number generator parameter values</u>. These values are used in the equation in Chapter 3.

```
a   =   16807
X0  =   16801
m   =   655362 - 1
```

B-2. <u>Sample analysis</u>.

```
Sample size............................. 500
Sample median........................... 0.5165
Sample mean............................. 0.50374
Sample variance......................... 0.0817265
Sample standard deviation............... 0.285879

Confidence interval for the mean at 95% and 499 DF.
             0.48623 <-------> 0.528871
```

B-3. <u>Tests for randomness</u>.

a. Kolmogorov-Smirnov test for uniform (0,1) distribution.

```
DPlus ................................ 0.021
DMinus ............................... 0.029
D .................................... 0.029
Approxmate significance level ........ 0.999969
```

b. Signs test for location of the median.

```
Hypothesized median .................. 0.5
# of values above hypothesized median  261
# of values below hypothesized median  239
Expected number ...................... 250
Large sample test statistic Z ........ 0.93914
Two-tailed probability of equaling or
    exceeding Z ...................... 0.347653
```

c. Runs test above and below the median.

```
# of runs above and below the median . 242
Expected number ...................... 251
Large sample test statistic Z ........ -0.761026
Two tailed probability of equaling or
    exceeding Z ...................... 0.446639
```

d. Runs test of ascending and descending runs.

\# of runs up and down 339
Expected number 332.333
Large sample test statistic Z 0.655921
Two tailed probability of equaling or
exceeding Z 0.511872

e. Autocorrelation test.

Tested for lags from 1 to 100.
Most significant deviation at lag of 16.
H0: Correlation = 0
H1: Correlation = 0
p value for rejection of H0 = .406

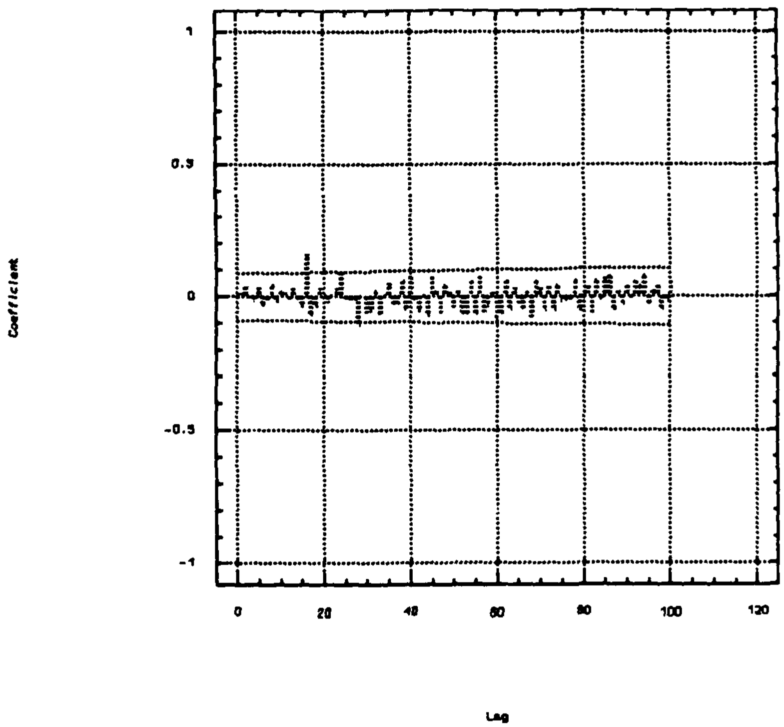


Figure B-1. Estimated autocorrelations

APPENDIX C

DETECTION/ACQUISITION TABLES AND FIGURES

Table C-1. Terrain/background mapping

Code	Terrain	Background
T1	Flat bare	Open
T2	Flat medium	Wooded
T3	Flat dense	Wooded
T4	Rolling bare	Open
*T5	Rolling desert	No assignment
T6	Rolling medium	Wooded
T7	Rolling dense	Wooded
T8	Rugged bare	Open
T9	Rugged medium	Wooded
T10	Rugged dense	Wooded
T11	Urban	Urban
*T12	Road	Urban
T13	Swamp	Wooded
*T14	Bridge	Wooded
T15	Fordable water	Open
*T16	Deep water	Wooded

* indicates questionable assignment

Table C-2. Sensitivity test baseline

Light Level	1 (100 foot candles)
Target	Tank
Target Status	Hull-down
Target Activity	Inactive
Terrain	Open
Sky-to-Ground Ratio	5.0
Scan Rate	1.7 seconds
Acquisition Level	2.5
Scan Elevation	20.0 degrees
Scan Azimuth	30.0 degrees
Time of Day	Noon
Visual Contrast	0.4
Thermal Contrast	2.0
Tank Thermal Attenuation	0.168

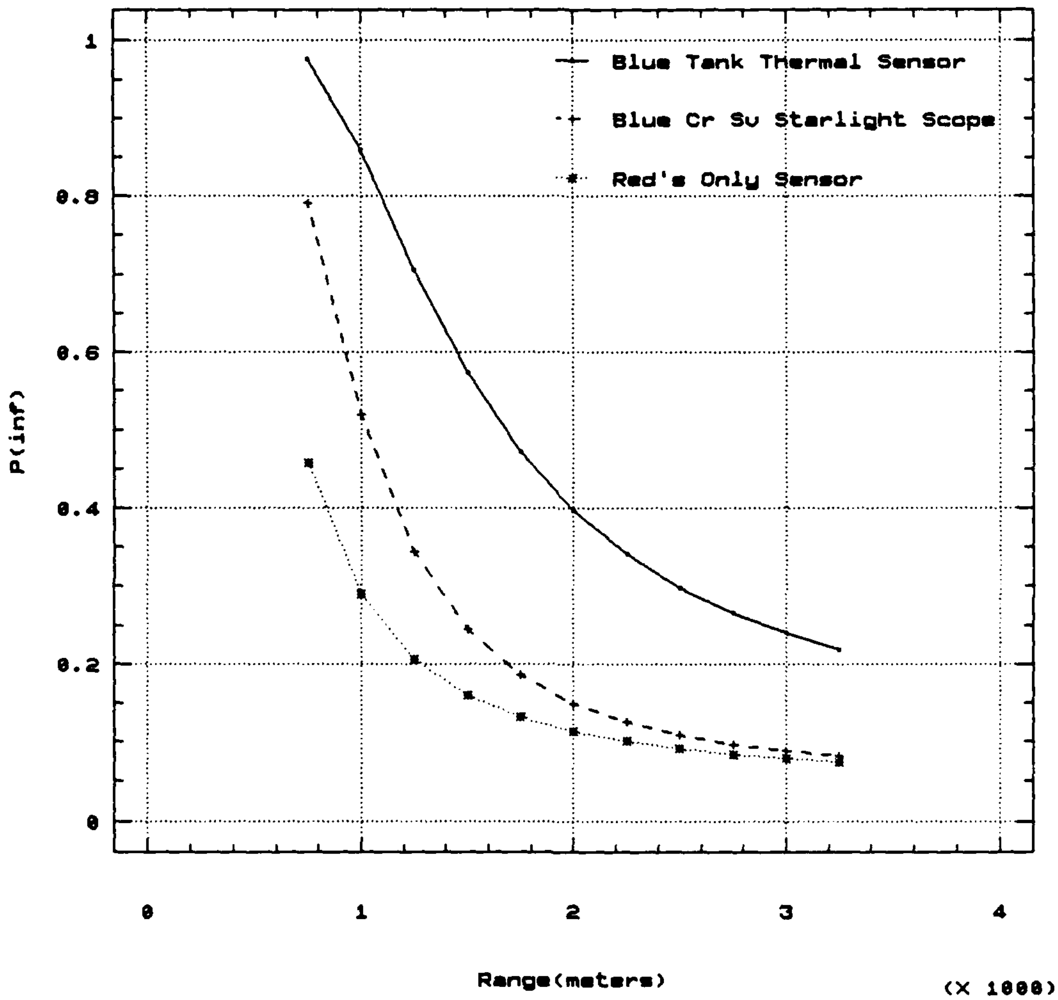


Figure C-1. Blue vs Red sensor capabilities

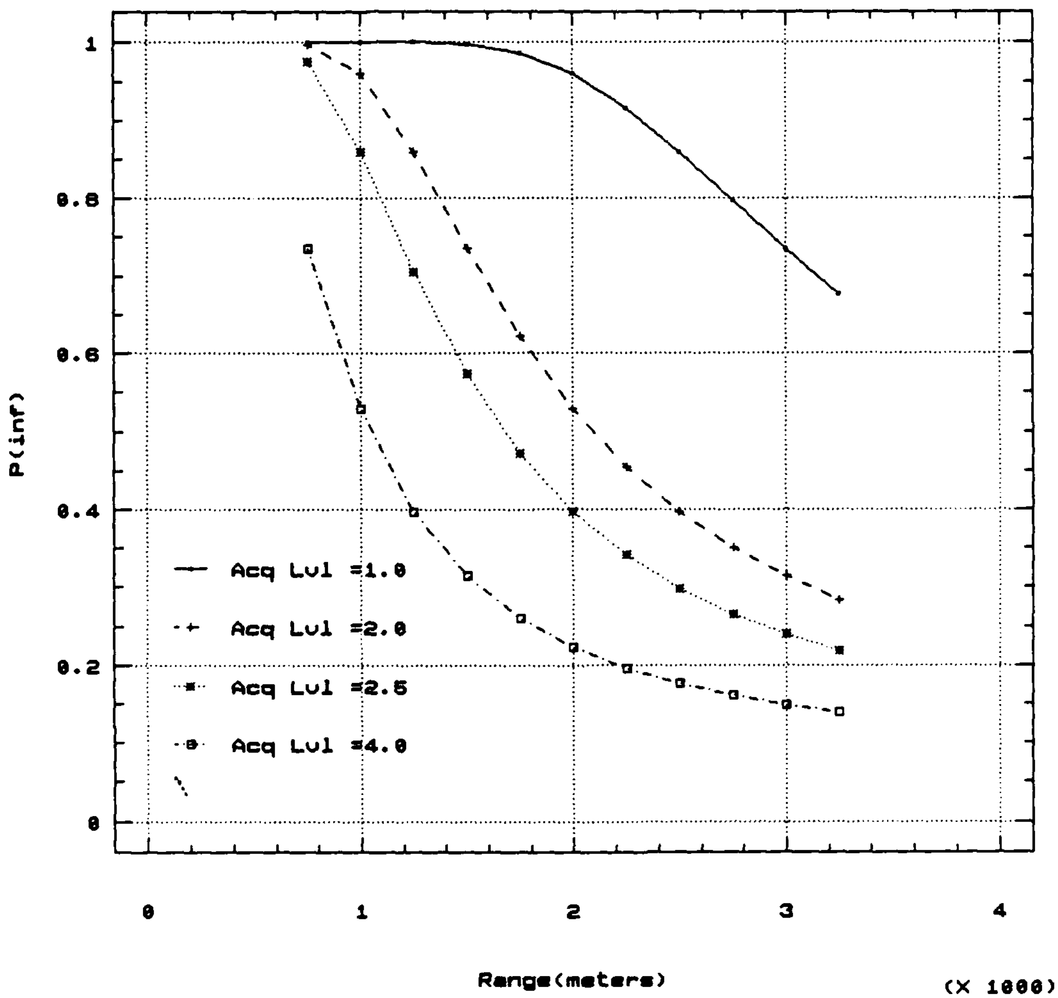


Figure C-2. Sensitivity of P(inf) to resolvable cycles

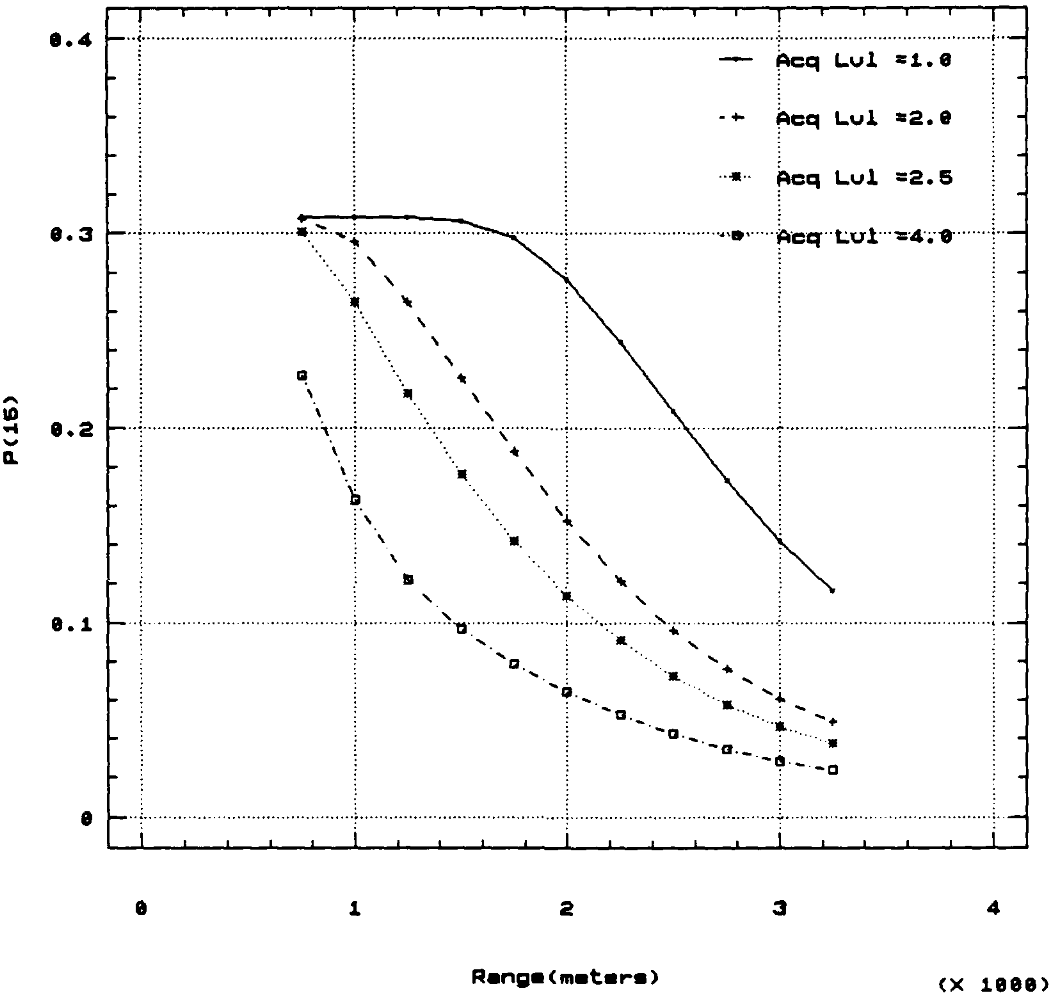


Figure C-3. Sensitivity of P(15) to resolvable cycles

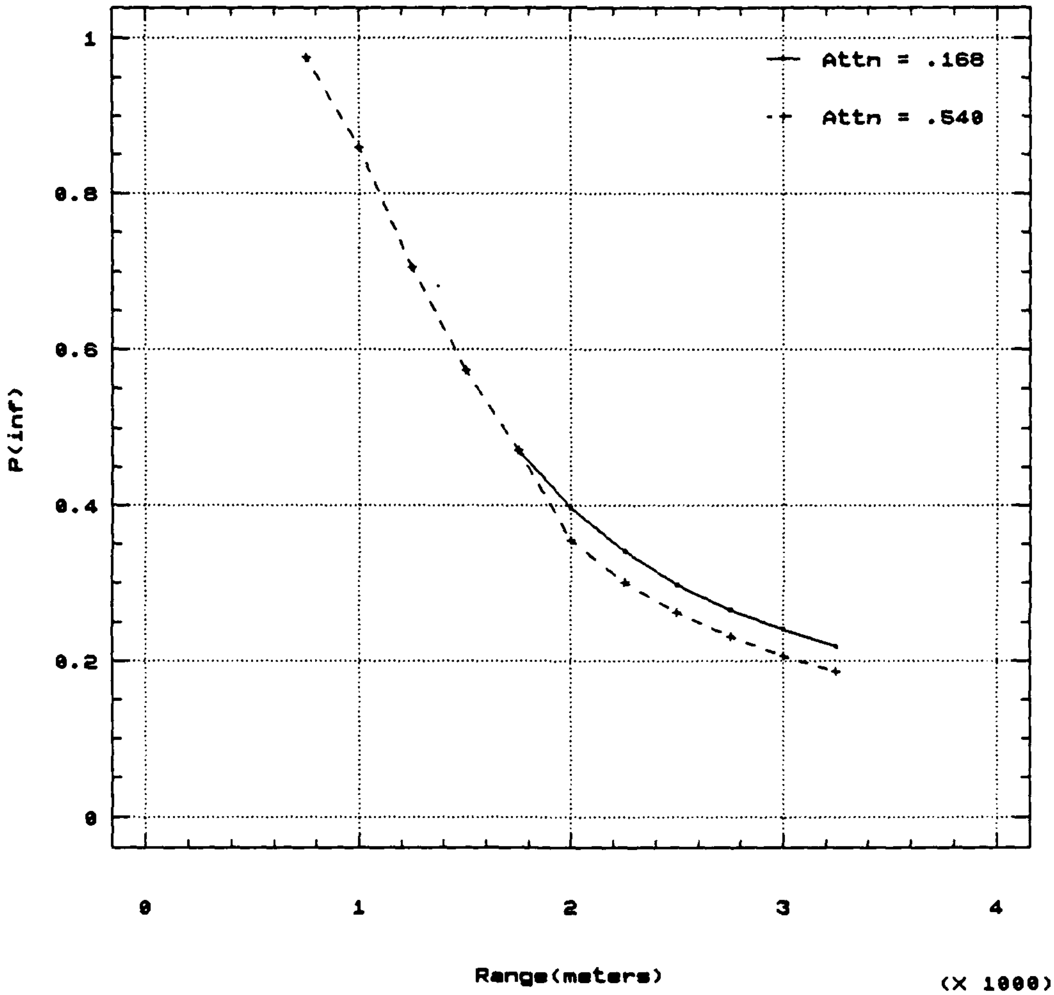


Figure C-4. Sensitivity of P(inf) to attenuation

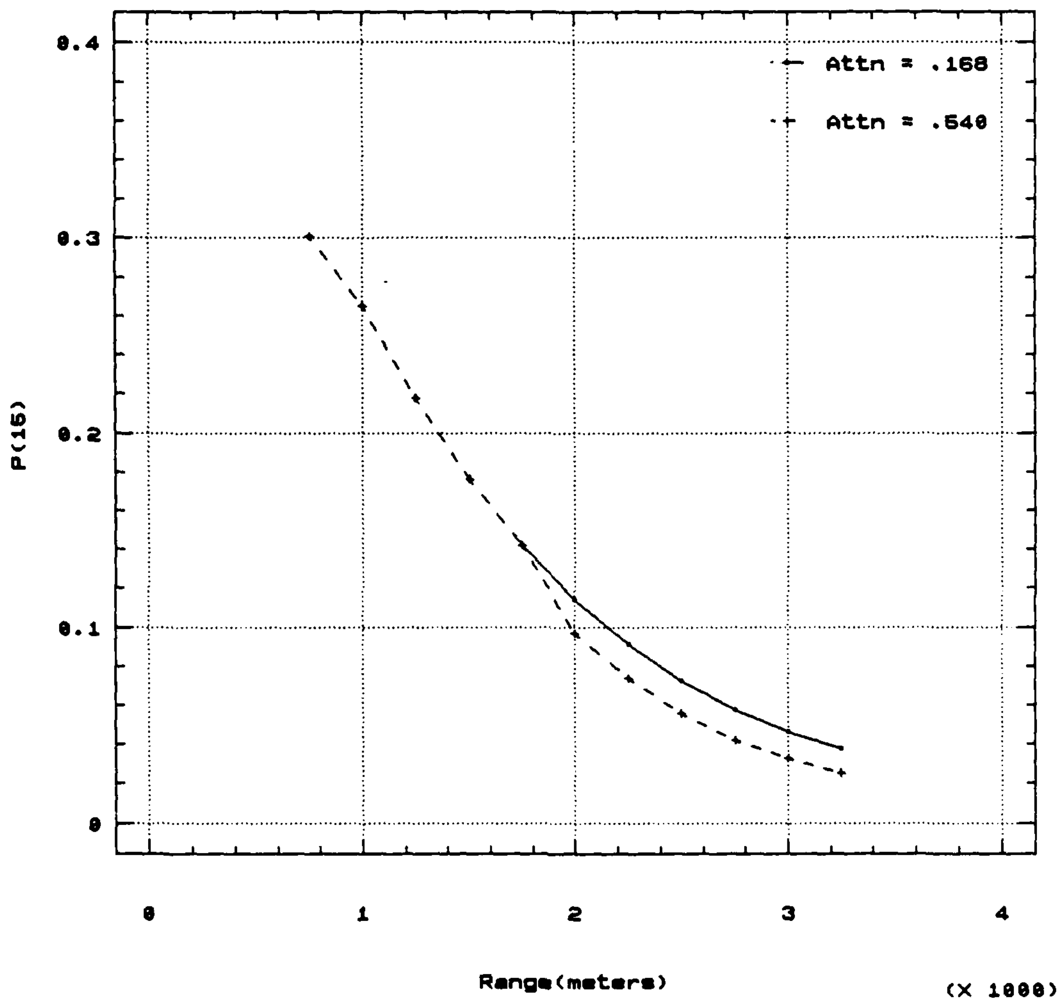


Figure C-5. Sensitivity of P(15) to attenuation

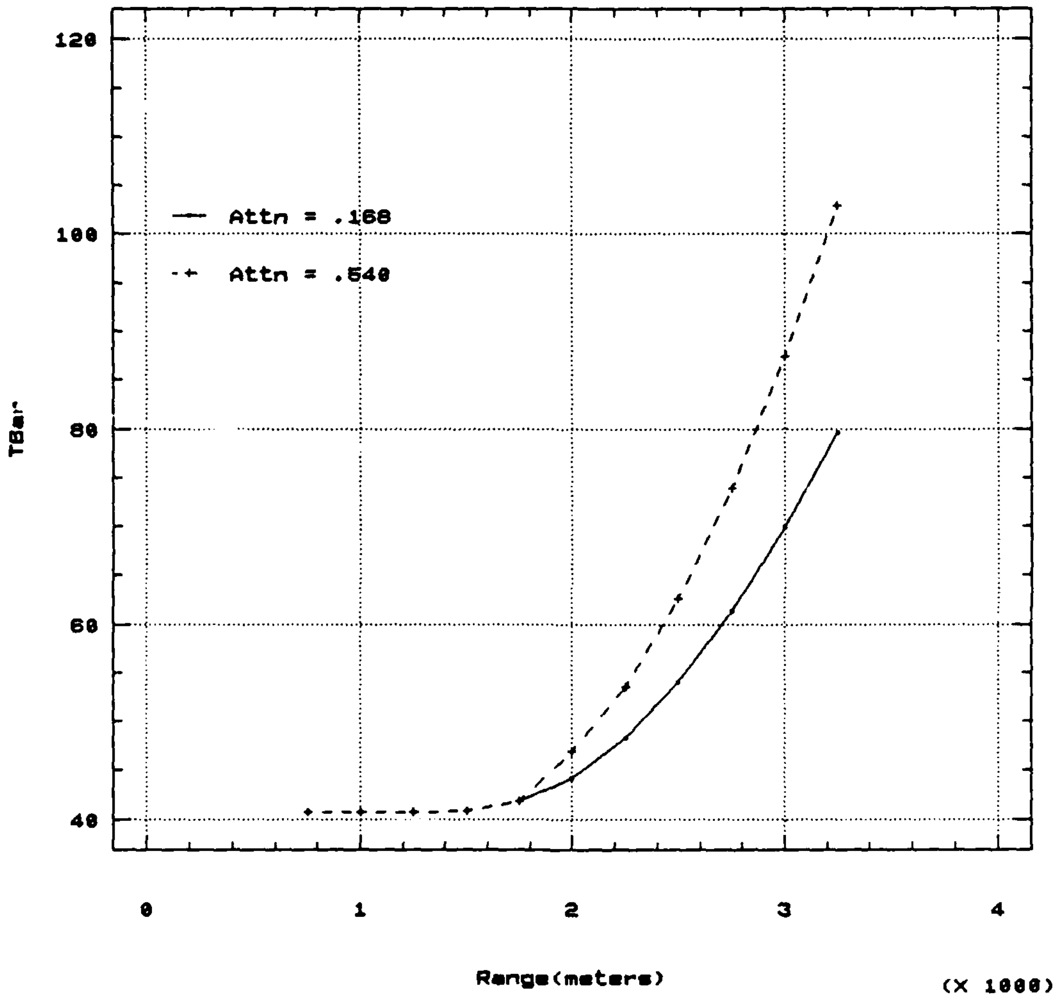


Figure C-6. Sensitivity of TBar to attenuation

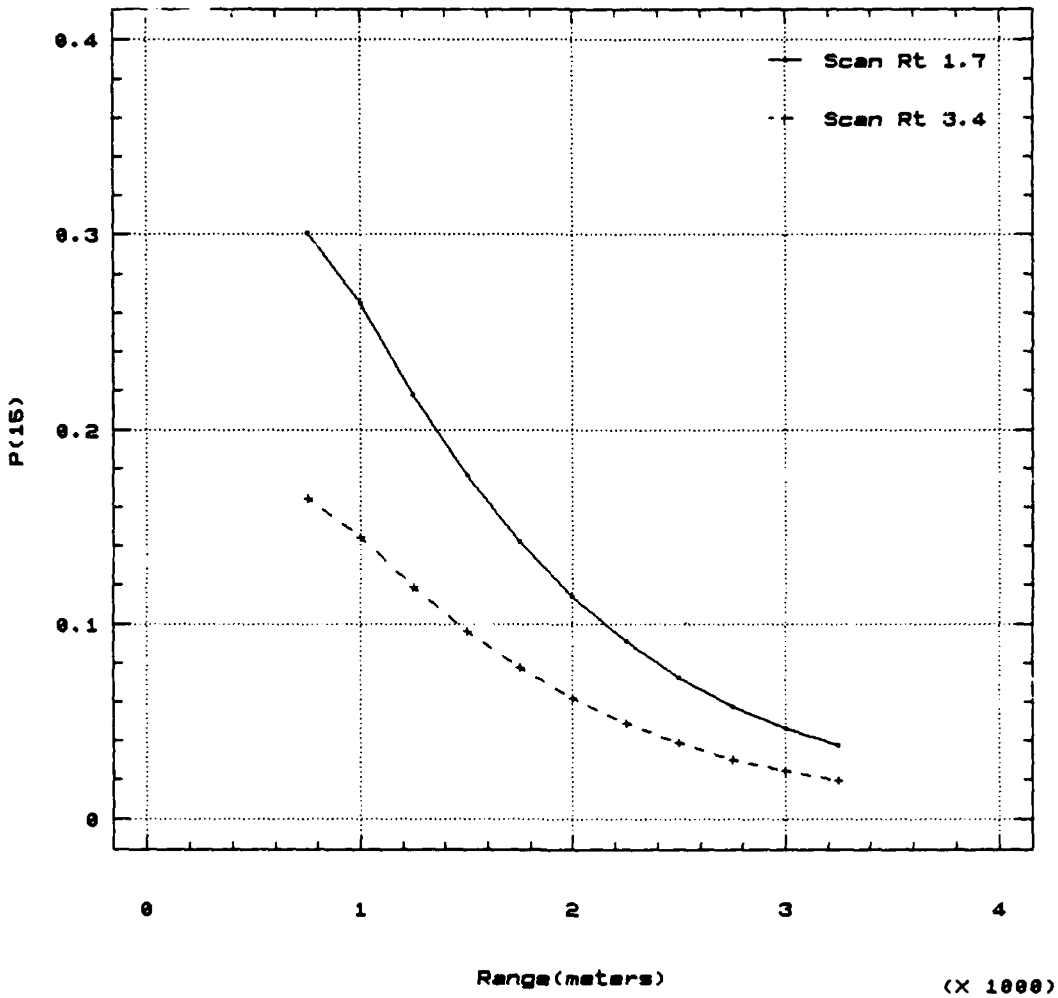


Figure C-7. Sensitivity of P(15) to scan rate

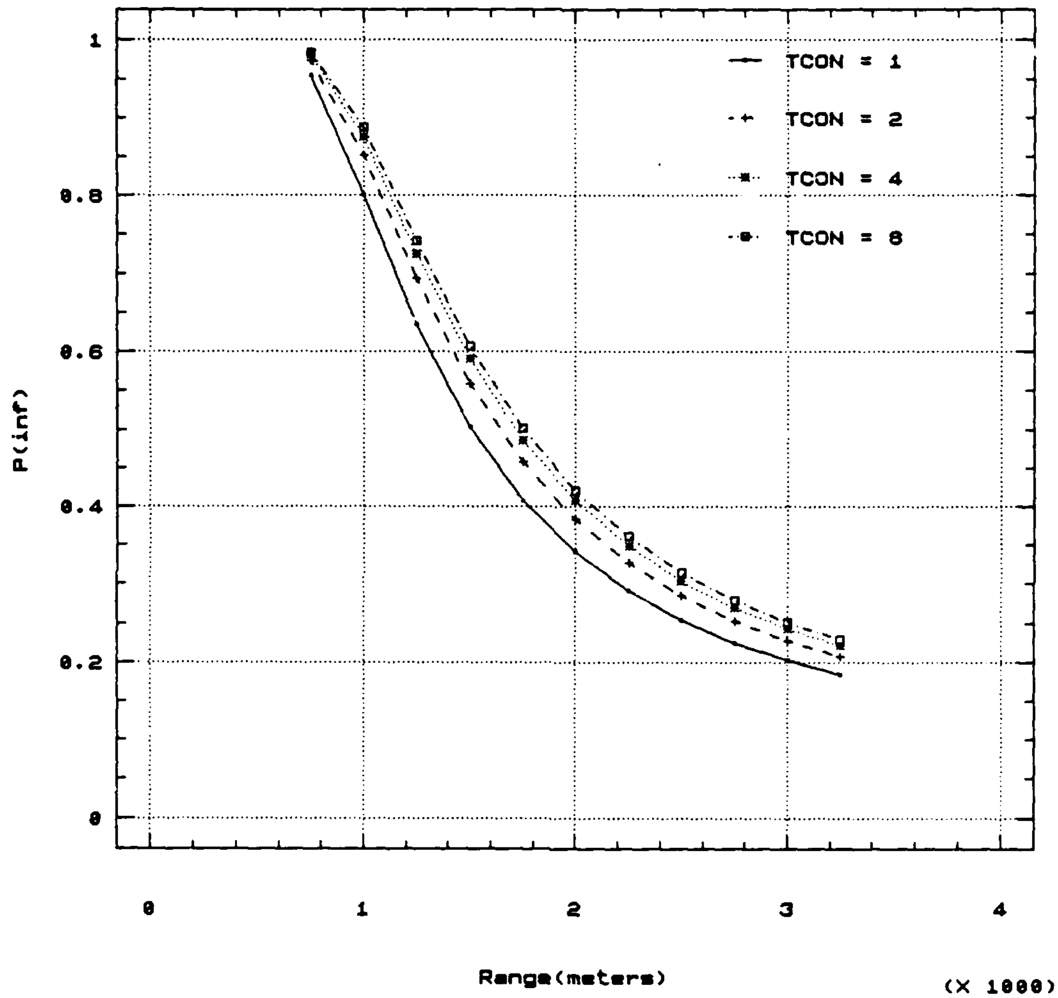


Figure C-8. Sensitivity of P(inf) to thermal contrast (TOW)

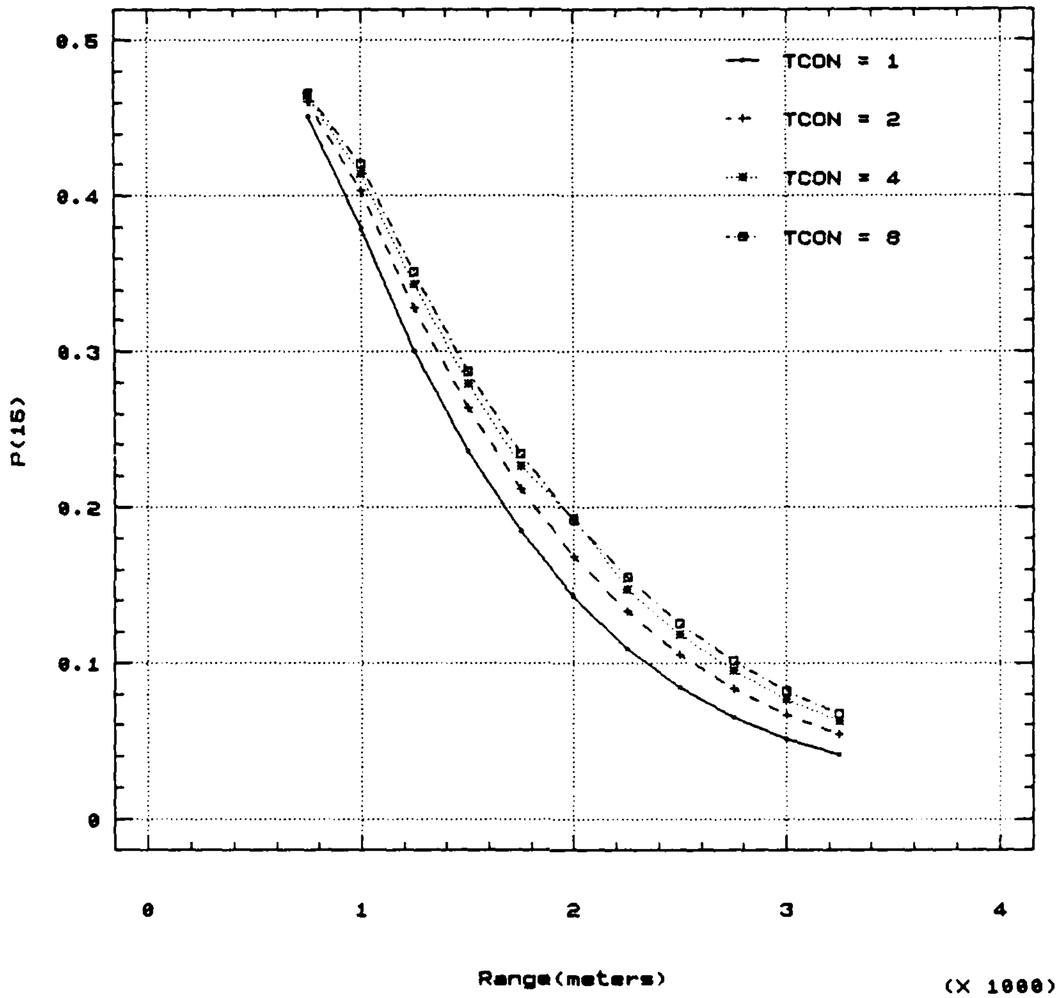


Figure C-9. Sensitivity of P(15) to thermal contrast (TOW)

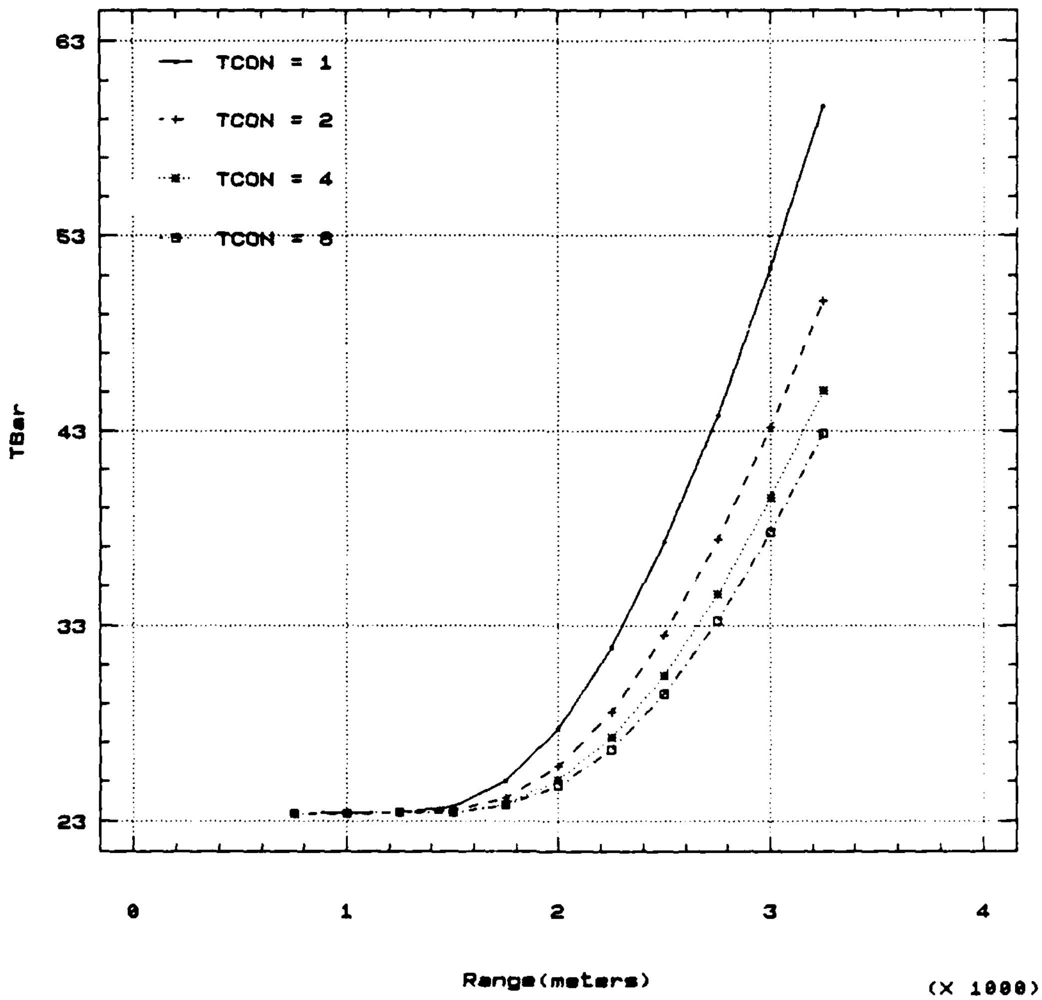


Figure C-10. Sensitivity of TBar to thermal contrast (TOW)

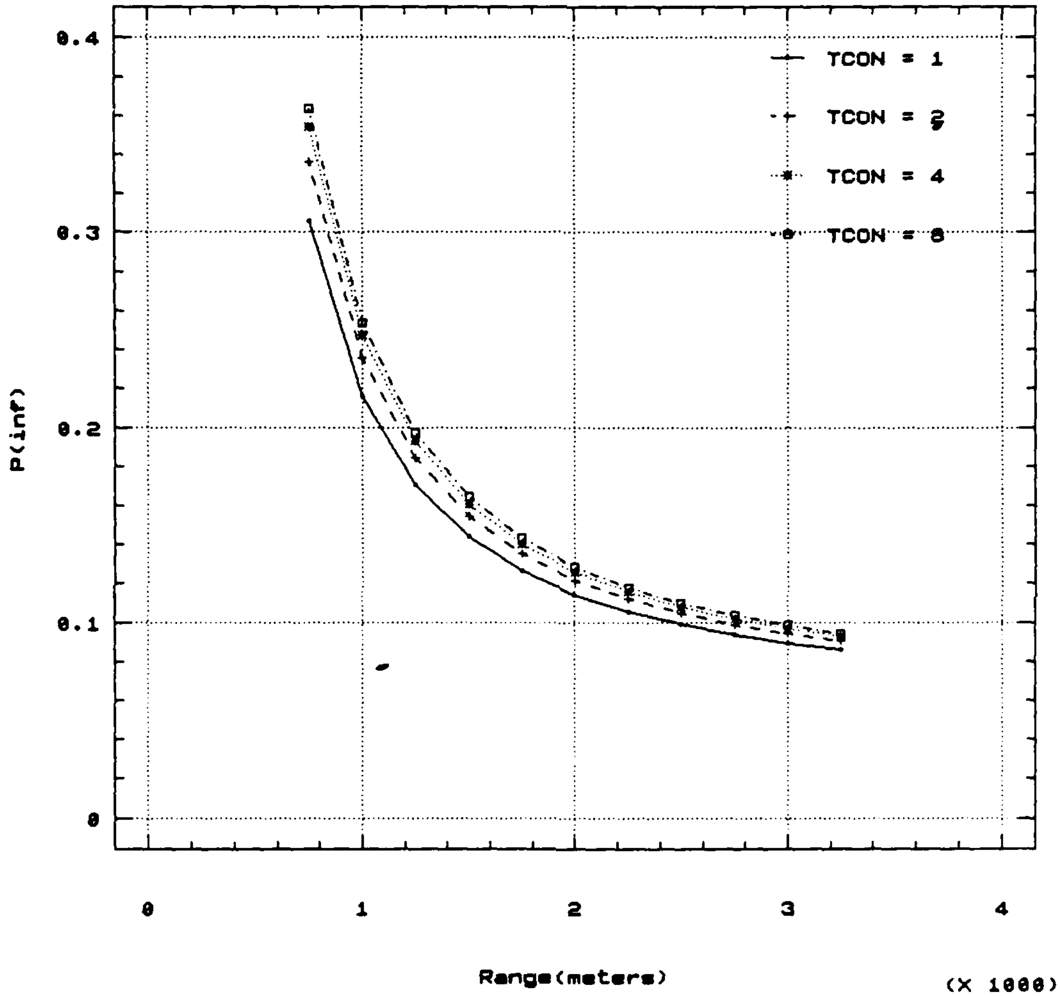
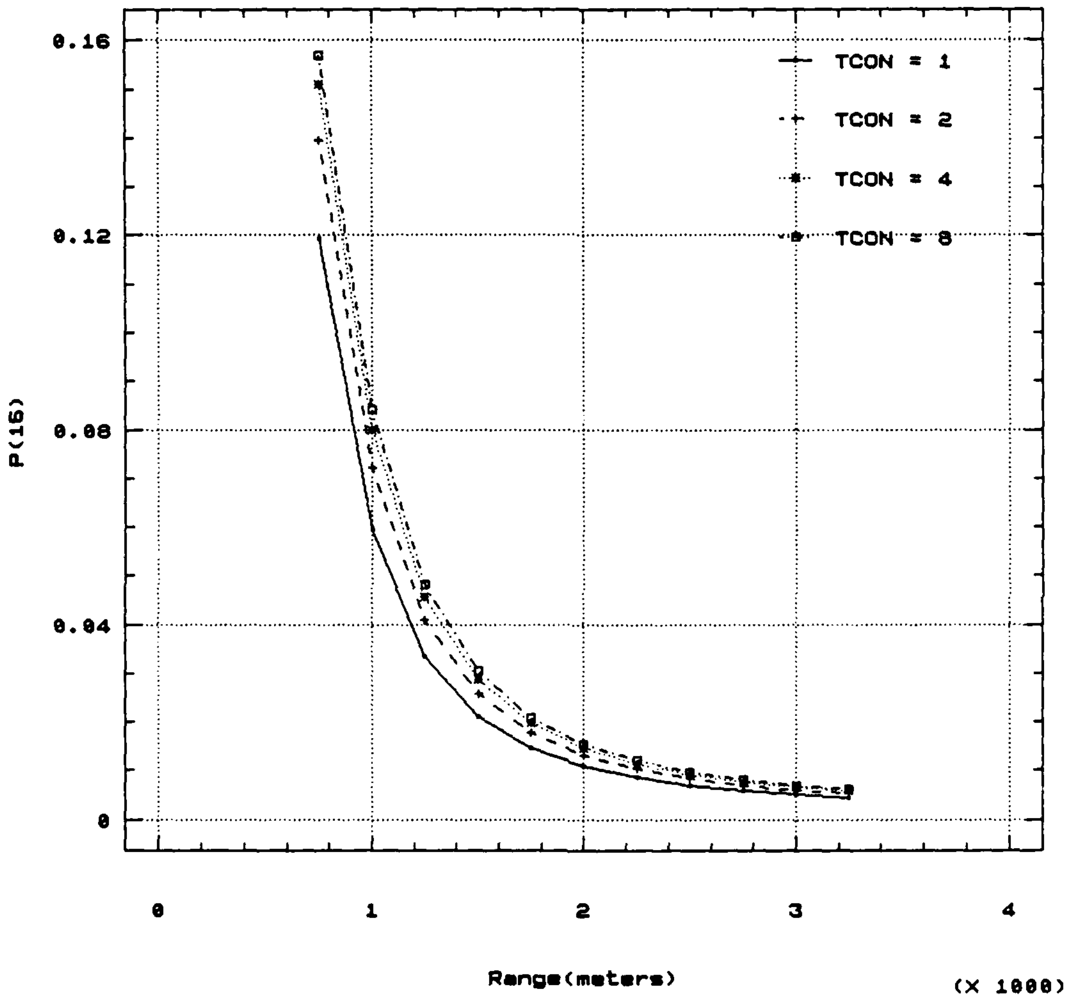


Figure C-11. Sensitivity of P(inf) to thermal contrast (Dragon)



Figur. C-12. Sensitivity of P(15) to thermal contrast (Dragon)

C-13

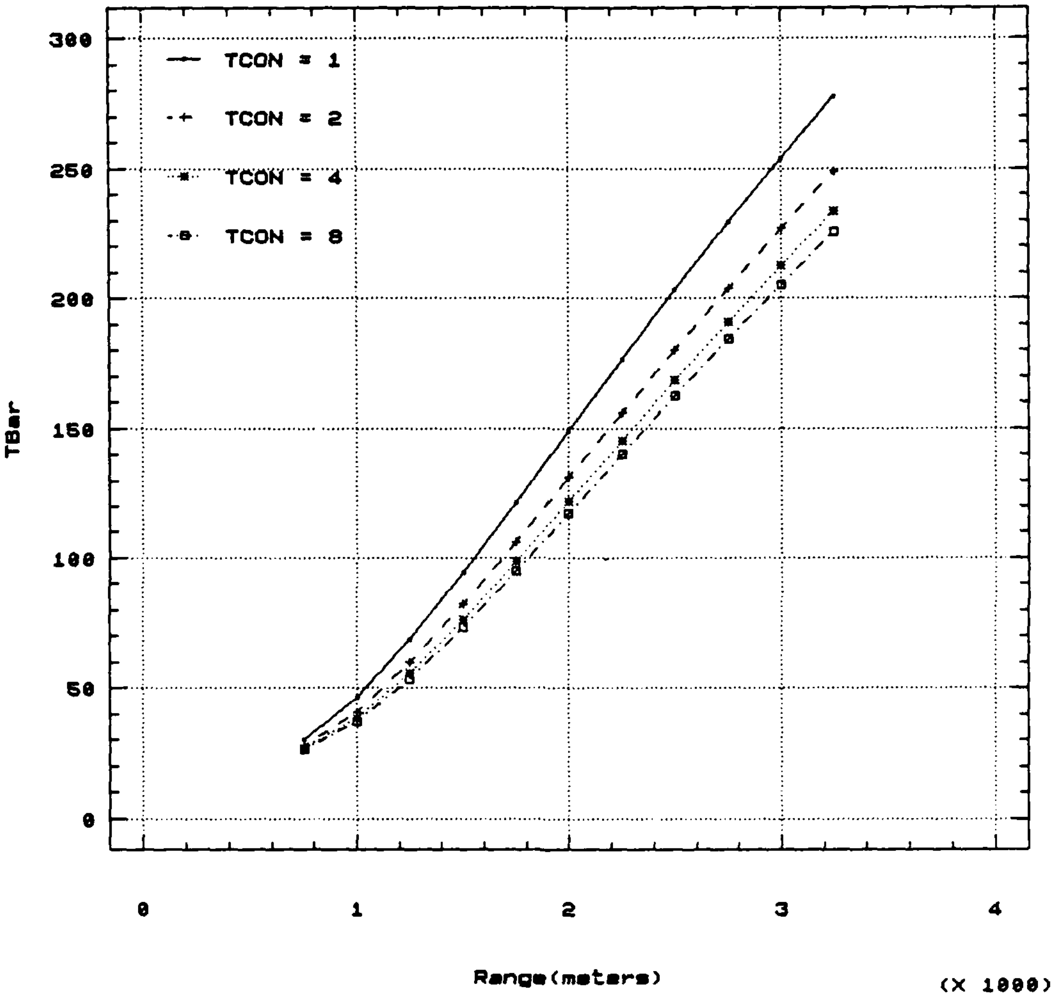


Figure C-13. Sensitivity of TBar to thermal contrast (Dragon)

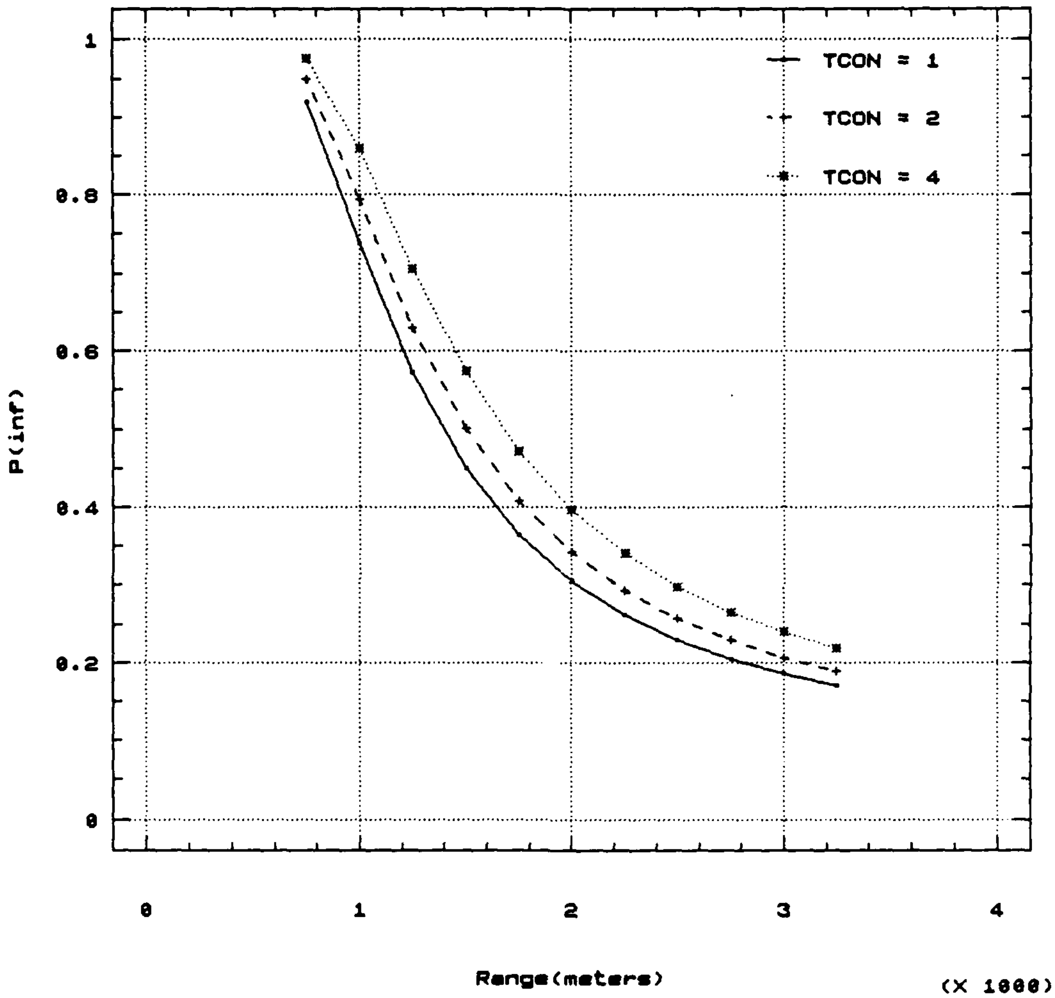


Figure C-14. Sensitivity of P(inf) to thermal contrast (Tank)

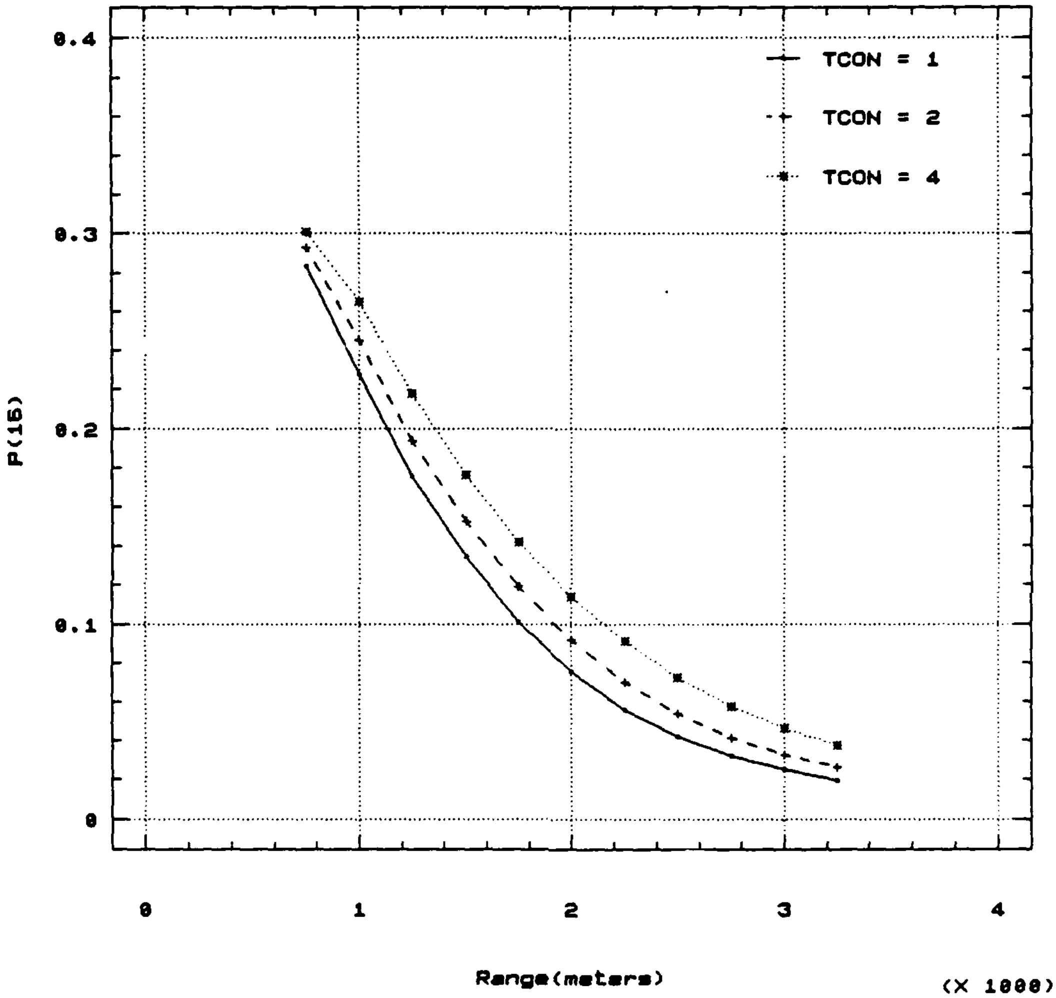


Figure C-15. Sensitivity of P(15) to thermal contrast (Tank)

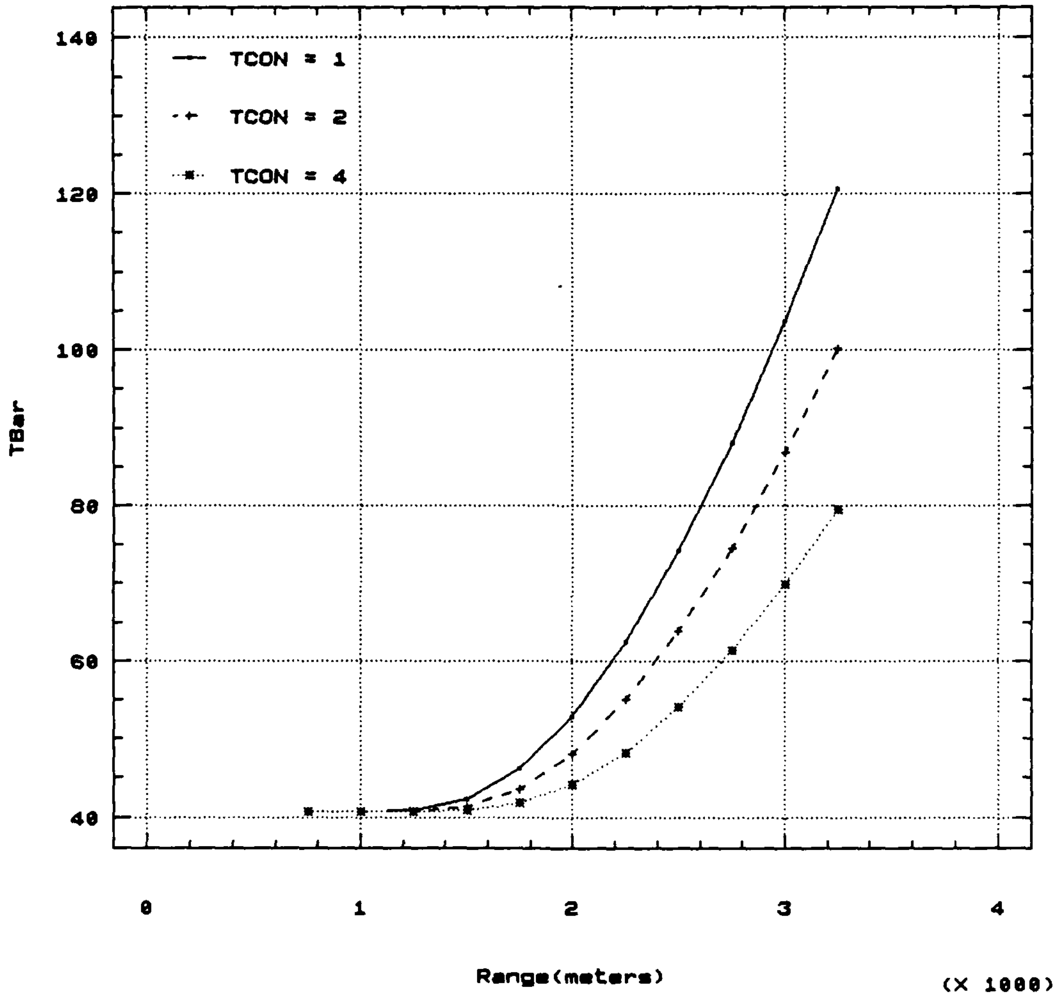


Figure C-16. Sensitivity of TBar to thermal contrast (Tank)

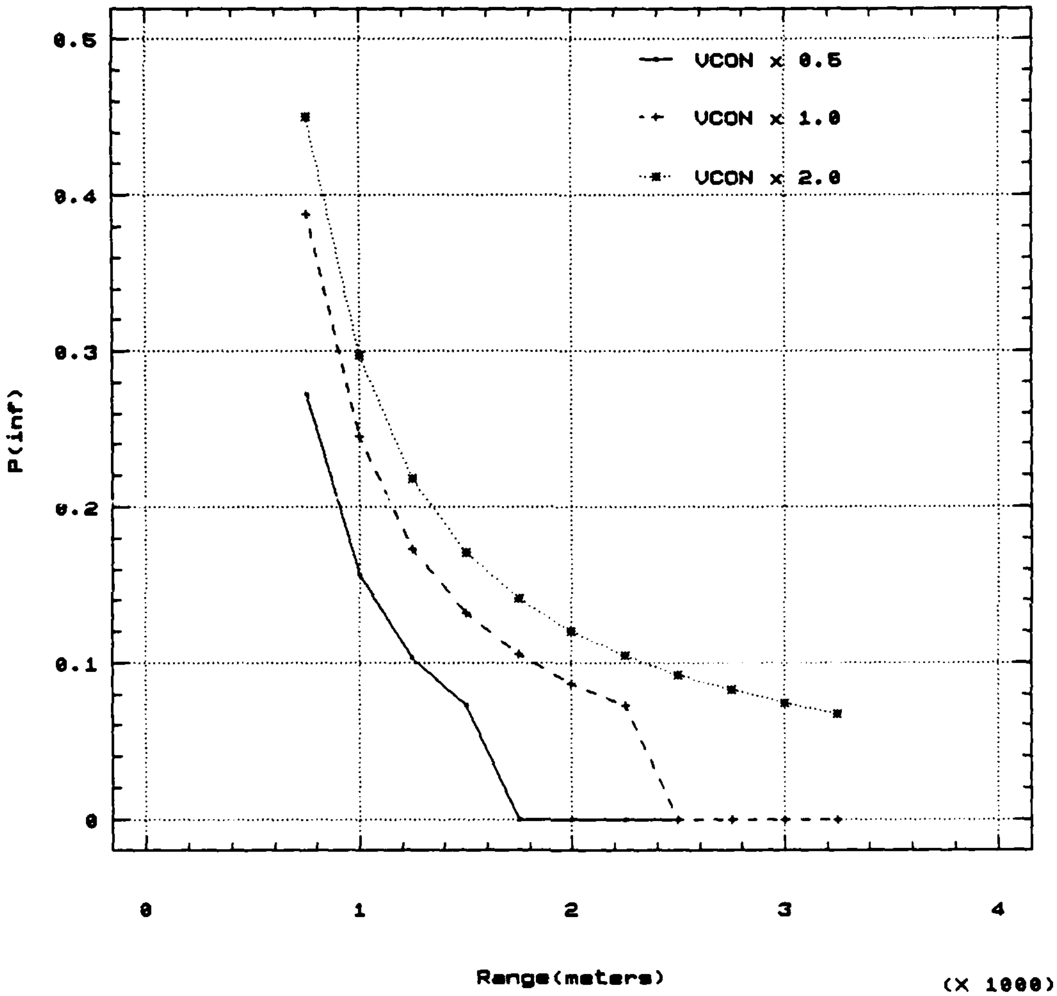


Figure C-17. Sensitivity of P(inf) to visual contrast (Eyes)

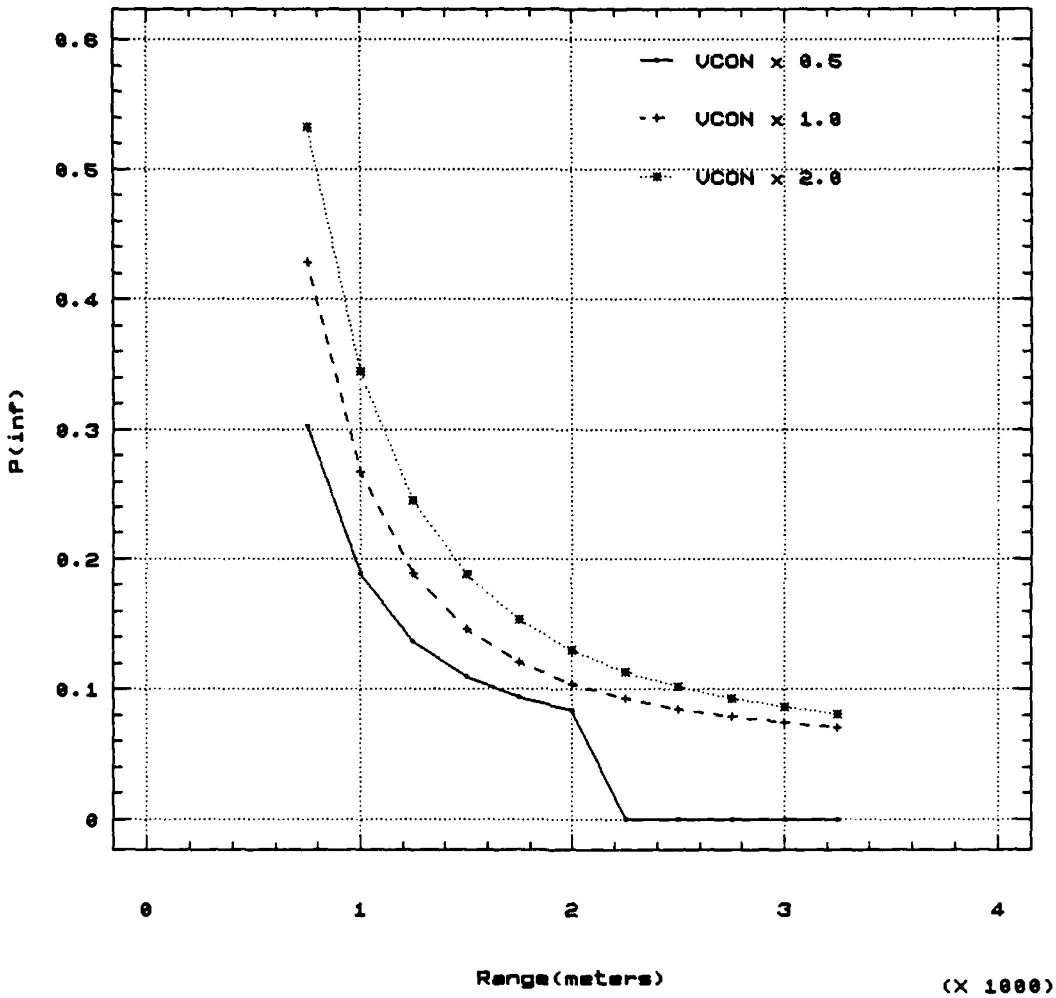


Figure C-18. Sensitivity of P(inf) to visual contrast (Scope)

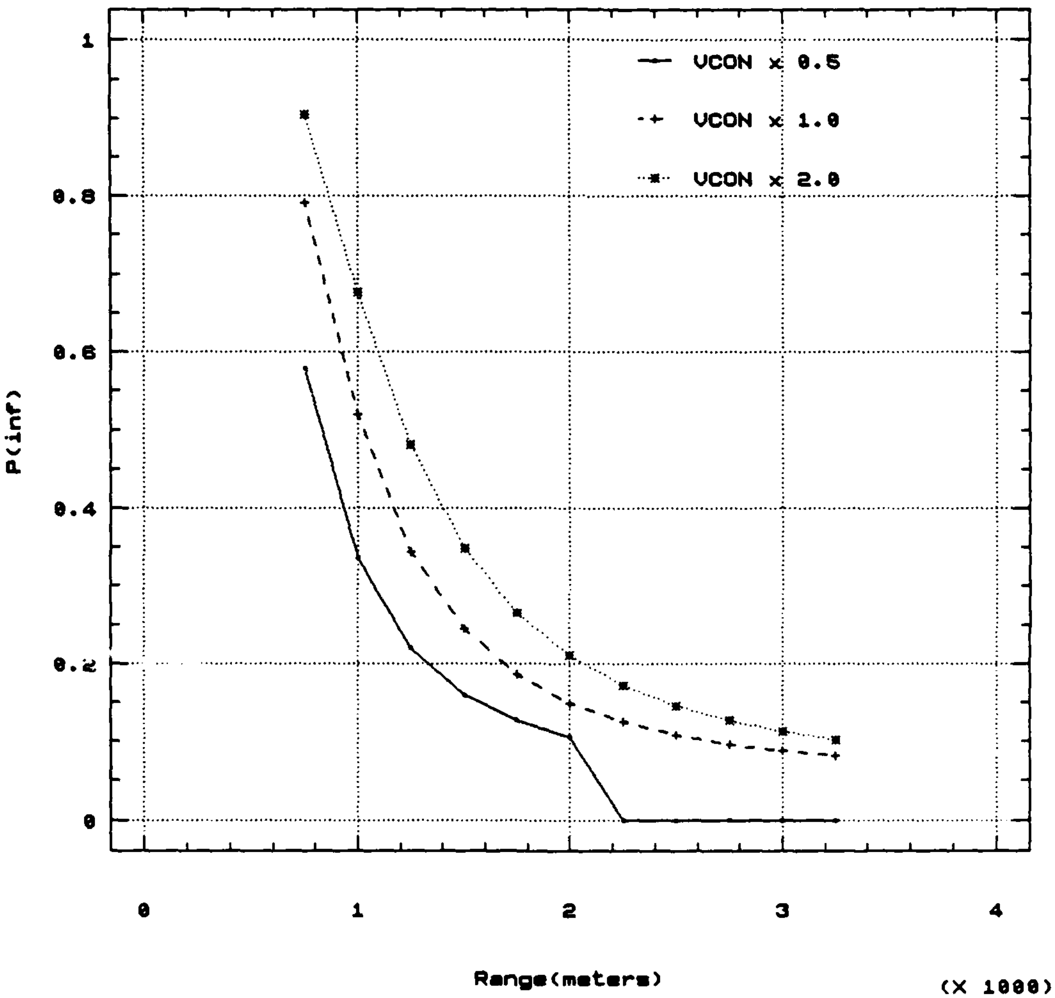


Figure C-19. Sensitivity of P(inf) to visual contrast (Cr Sv Starlight)

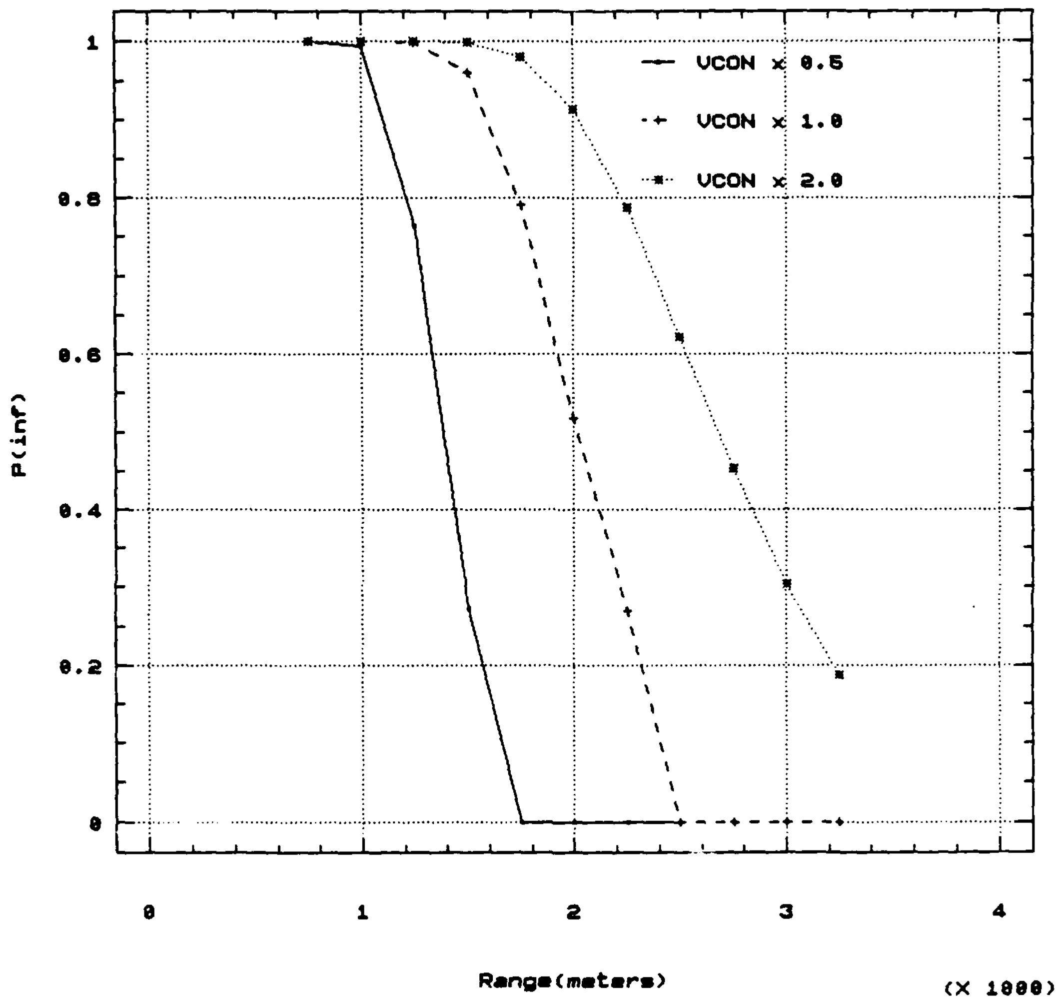


Figure C-20. Sensitivity of P(inf) to visual contrast (Binos)

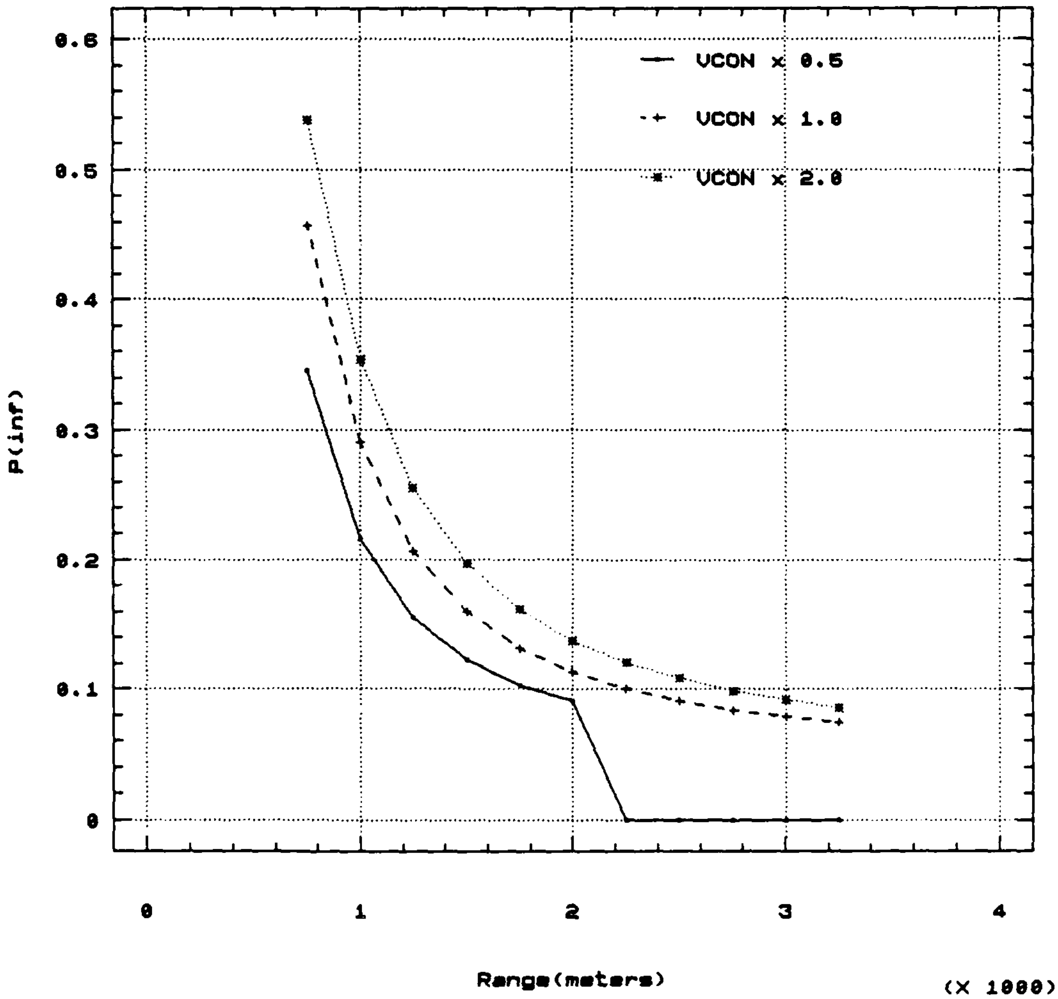


Figure C-21. Sensitivity of P(inf) to visual contrast (Enemy I**2)

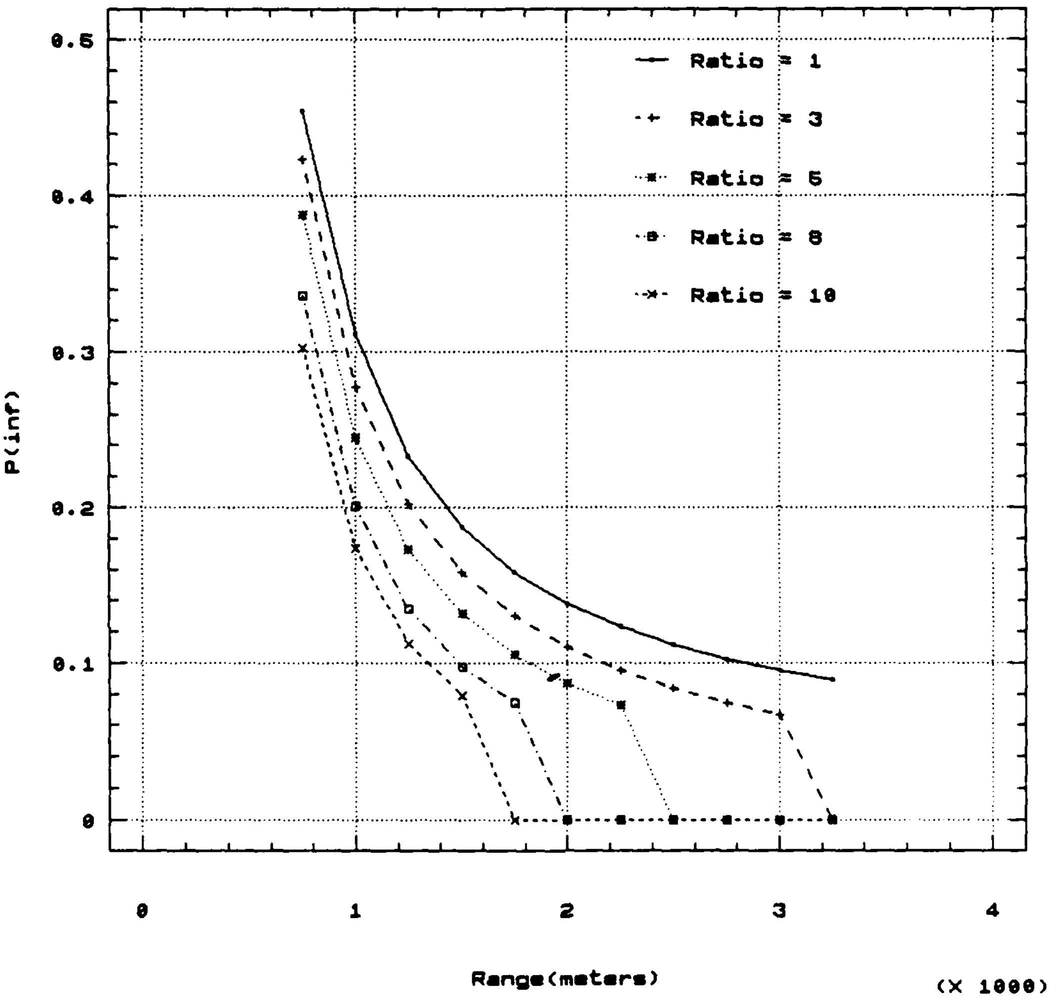


Figure C-22. Sensitivity of P(inf) to sky/ground ratio (Eyes)

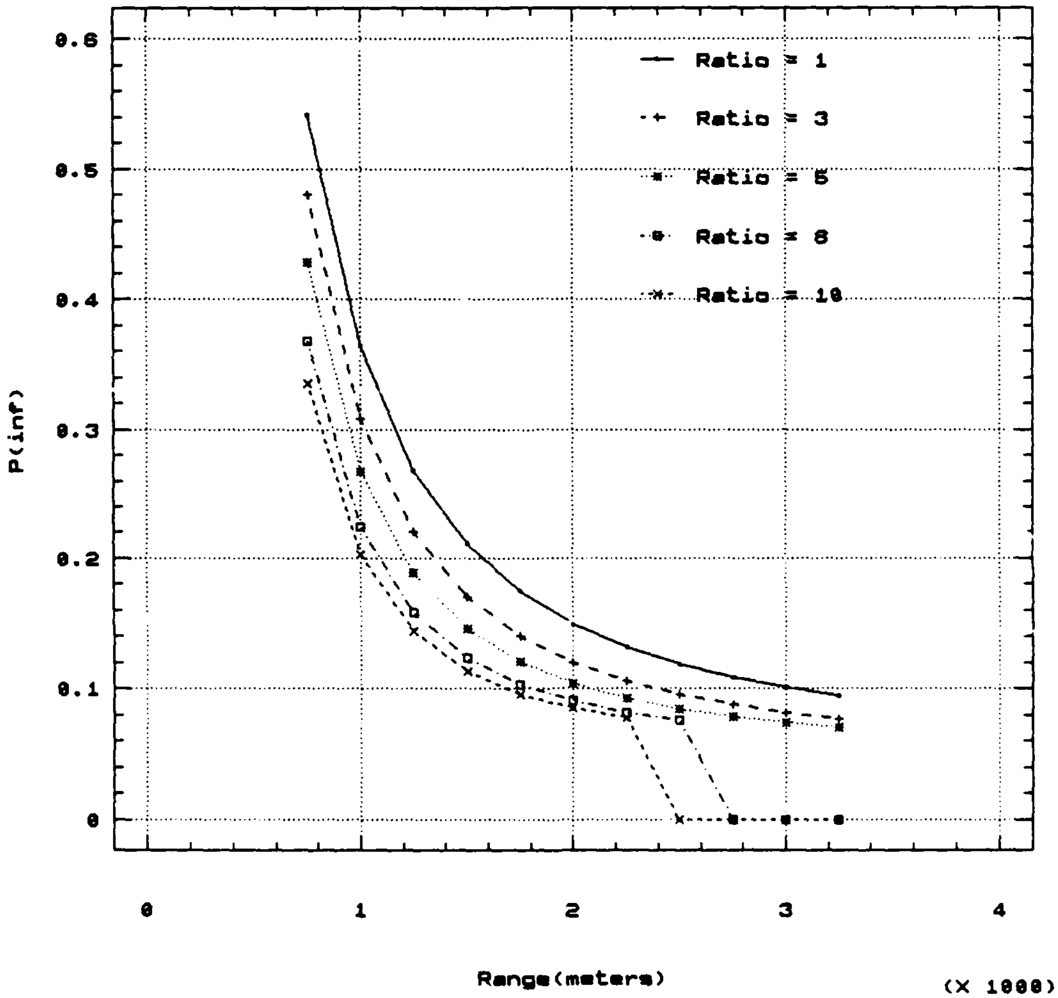


Figure C-23. Sensitivity of P(inf) to sky/ground ratio (Scope)

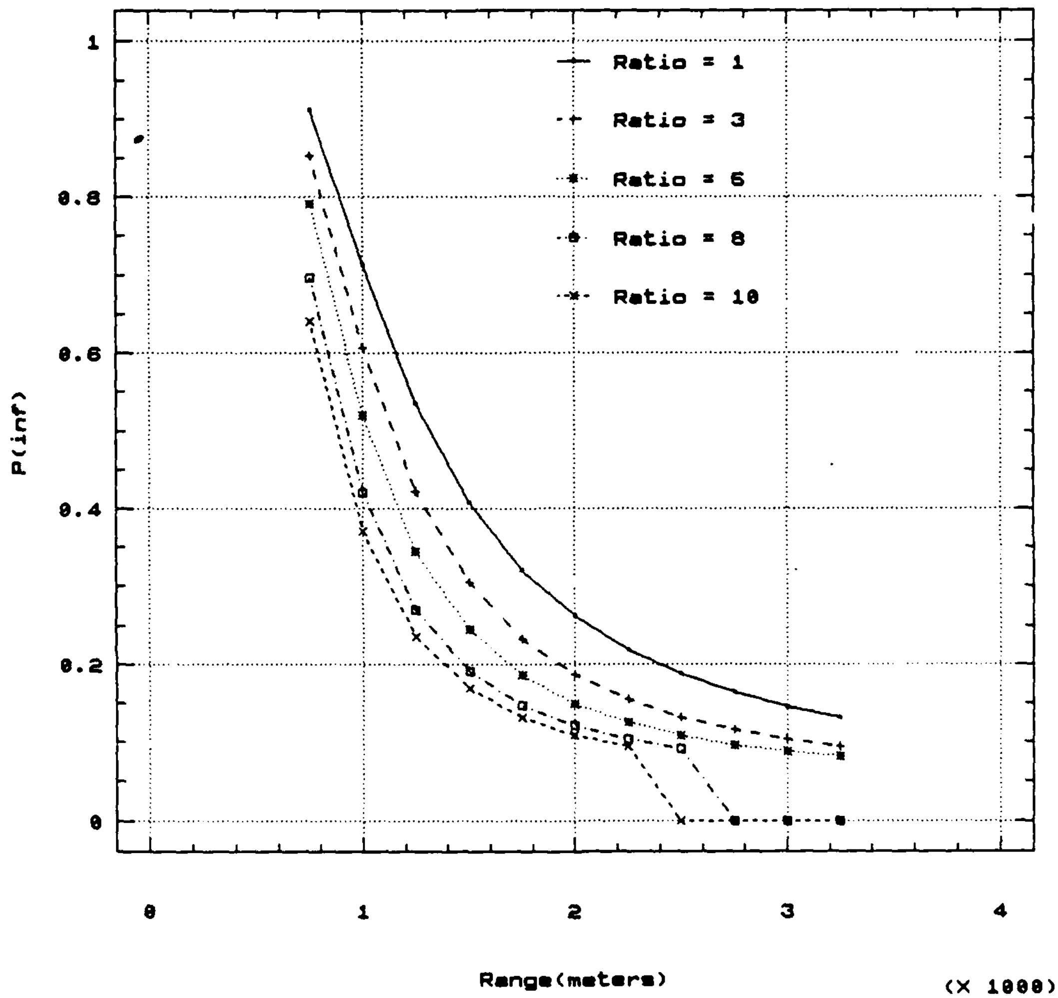


Figure C-24. Sensitivity of P(inf) to sky/ground ratio (Cr Sv Starlight)

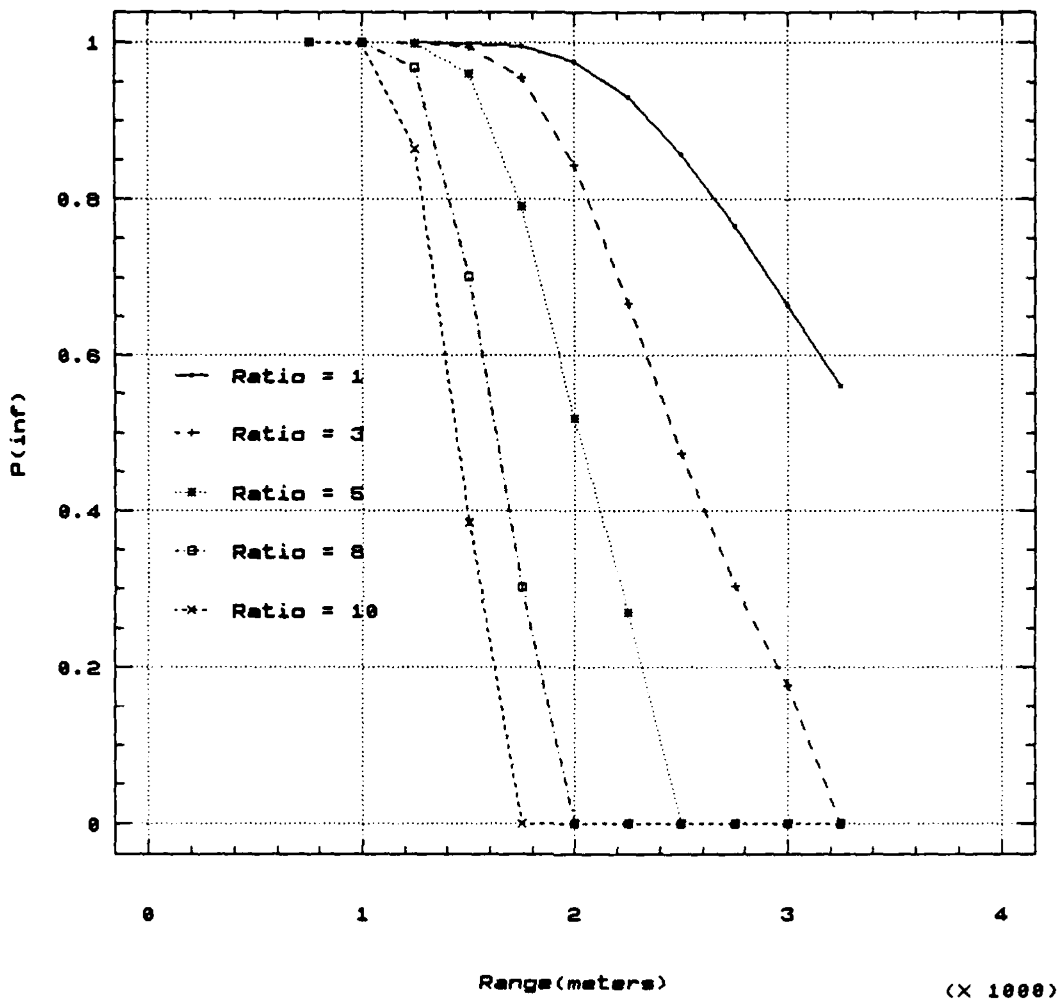


Figure C-25. Sensitivity of P(inf) to sky/ground ratio (Binos)

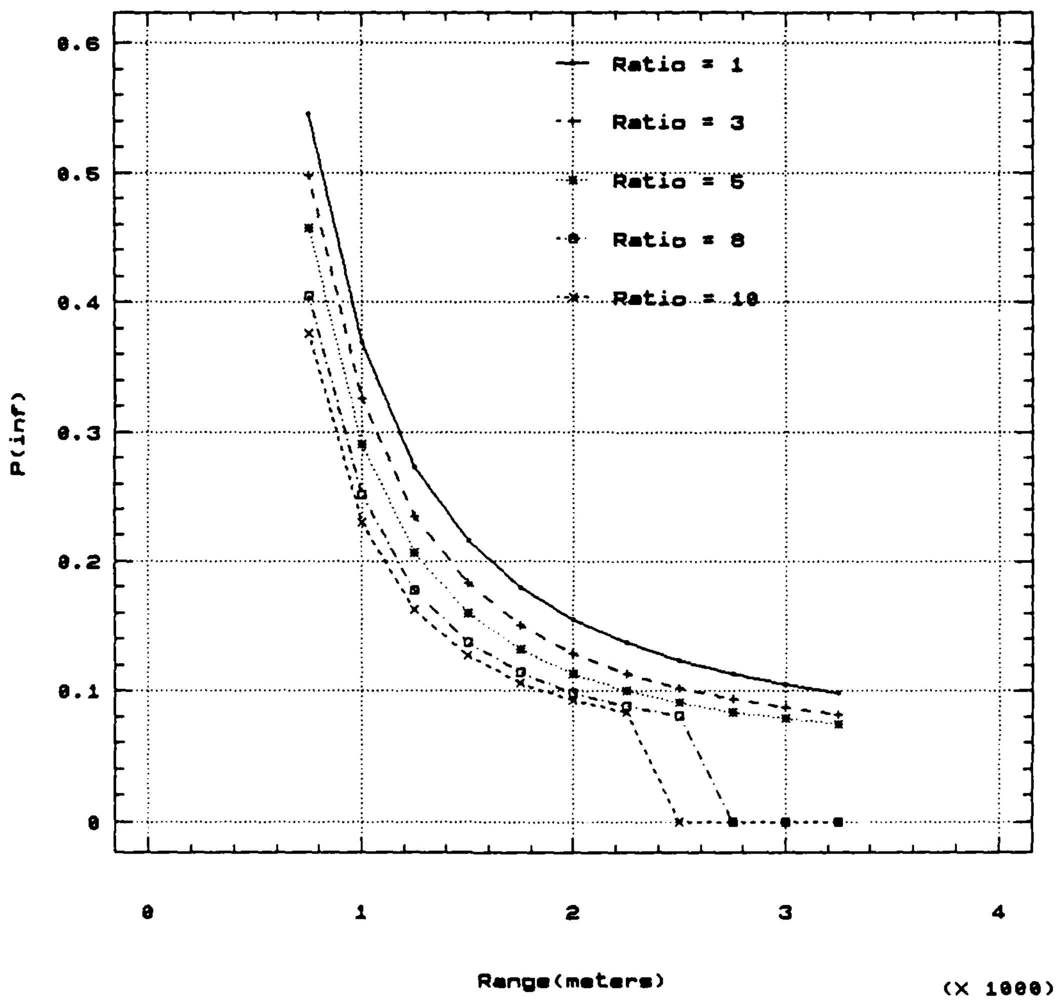


Figure C-26. Sensitivity of P(inf) to sky/ground ratio (Enemy I**2)

APPENDIX D

MOVEMENT TABLES AND FIGURES

Notes: Numeric values in tables D-1 through D-12 represent vehicle speeds in kilometers per hour.

"No go" refers to the condition that the vehicle cannot move in identified terrain cell.

Table D-1. CAMMS M1A1, terrain case 1

	Feb	Jul
SSRV	> 64	48 - 64
SRV	> 64	> 64
V	> 64	> 64

Table D-2. BBS tracked, terrain case 1

	Rugged bare(T-8)	Flat bare(T-1)
Terrain table only	12	50
Opstate - Travel-offroad	10	20

Table D-3. CAMMS M1A1, terrain case 2

	Feb	Jul
SSRV	No go	No go
SRV	48 - 64	48 - 64
V	> 64	> 64

Table D-4. BBS tracked, terrain case 2

	Rolling medium (T-6)
Terrain table only	10
Opstate - Travel-offroad	10

Table D-5. CAMMS M1A1, terrain case 3

	Feb	Jul
SSRV	No go	No go
SRV	No go	No go
V	No go	No go

Table D-6. BBS tracked, terrain case 3

	Rolling dense (T-7)
Terrain table only	7
Opstate - Travel-offroad	7

Table D-7. CAMMS M977, terrain case 1

	Feb	Jul
SSRV	16 - 32	16 - 32
SRV	16 - 32	16 - 32
V	> 64	> 64

Table D-8. BBS wheeled, terrain case 1

	Rugged bare(T8)	Flat bare(T1)
Terrain table only	10	70
Opstate - Travel-offroad	10	20

Table D-9. CAMMS M977, terrain case 2

	Feb	Jul
SSRV	No go	No go
SRV	16 - 32	16 - 32
V	> 64	> 64

Table D-10. BBS wheeled, terrain case 2

	Rolling medium (T6)
Terrain table only	10
Opstate - Travel-offroad	10

Table D-11. CAMMS M977, terrain case 3

	Feb	Jul
SSRV	No go	No go
SRV	No go	No go
V	No go	No go

Table D-12. BBS wheeled, terrain case 3

	Rolling dense (T7)
Terrain table only	4
Opstate - Travel-offroad	4

AVERAGE RATES OF MARCH: **KMPH**

UNITS	ON ROADS DAY	ON ROADS NIGHT	CROSS-COUNTRY DAY	CROSS-COUNTRY NIGHT	KM DAYS
FOOT TROOPS	4	3.2	2.4	1.6	20-32
TRUCKS, GENERAL	40	40 (LIGHTS) 16 (BLACKOUT)	12	8	280
TRACKED VEHICLES	24	24 (LIGHTS) 16 (BLACKOUT)	16	8	240
TRUCK-DRAWN ARTILLERY	40	40 (LIGHTS) 16 (BLACKOUT)	12	8	280
TRACTOR-DRAWN ARTILLERY	32	32 (LIGHTS) 16 (BLACKOUT)	16	8	240

*This table is for general planning and comparison purposes. All rates given are variable in accordance with the movement conditions as determined by reconnaissance.

Extracted from FM 7-20, The Infantry Battalion

Figure D-1. Average rates of march

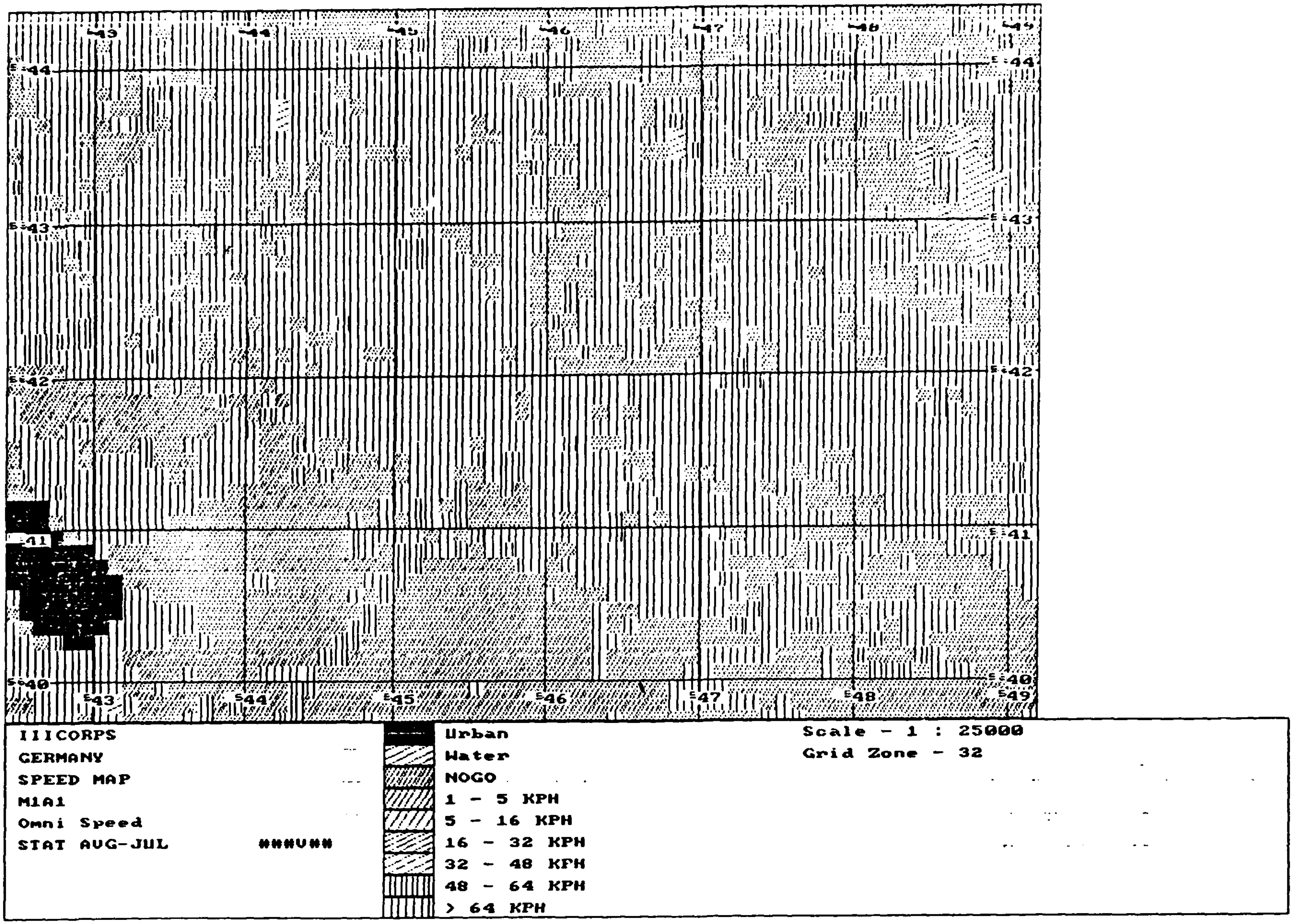


Figure D-2. M1A1, July, Veg Only

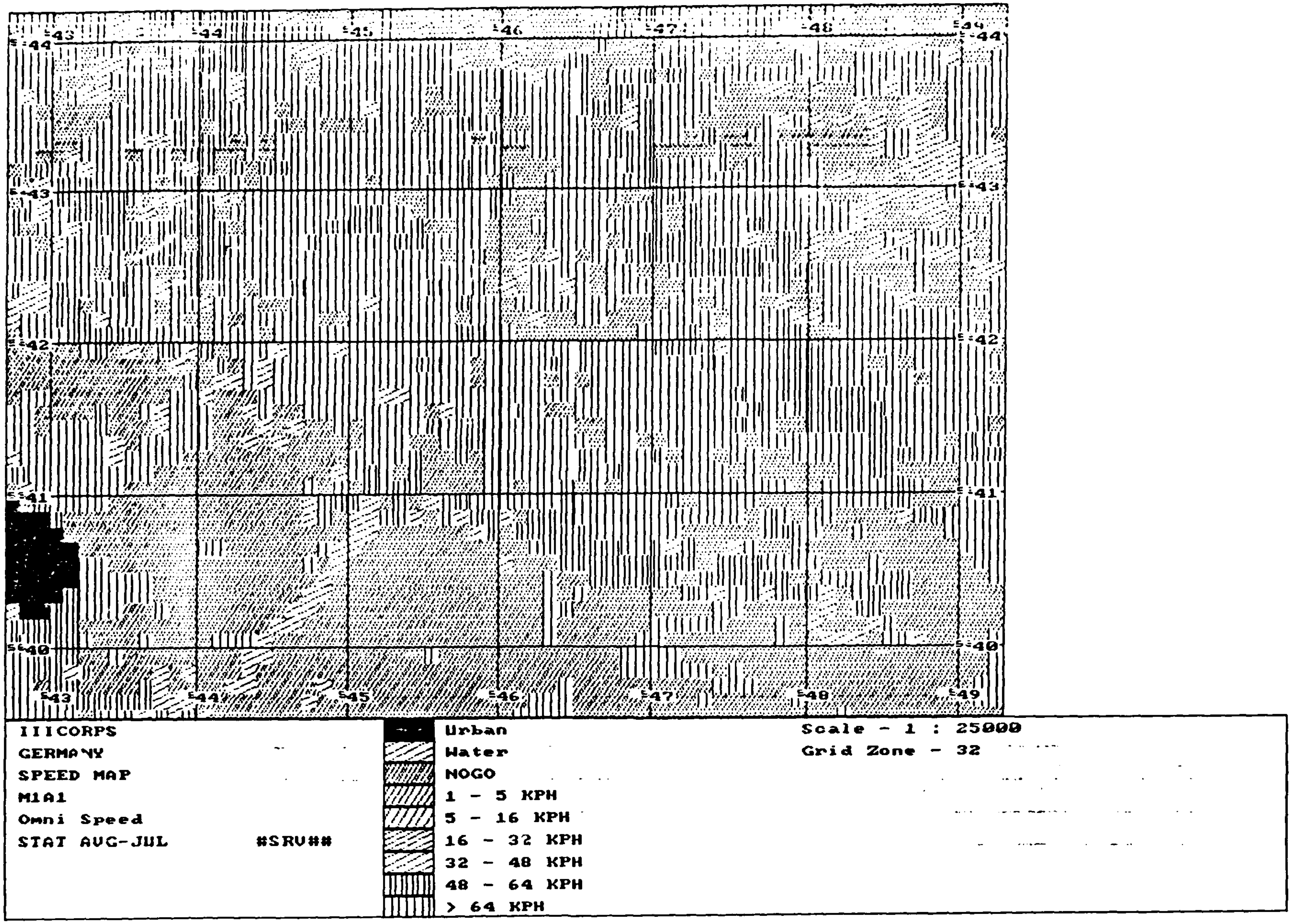


Figure D-3. M1A1, July, SRV

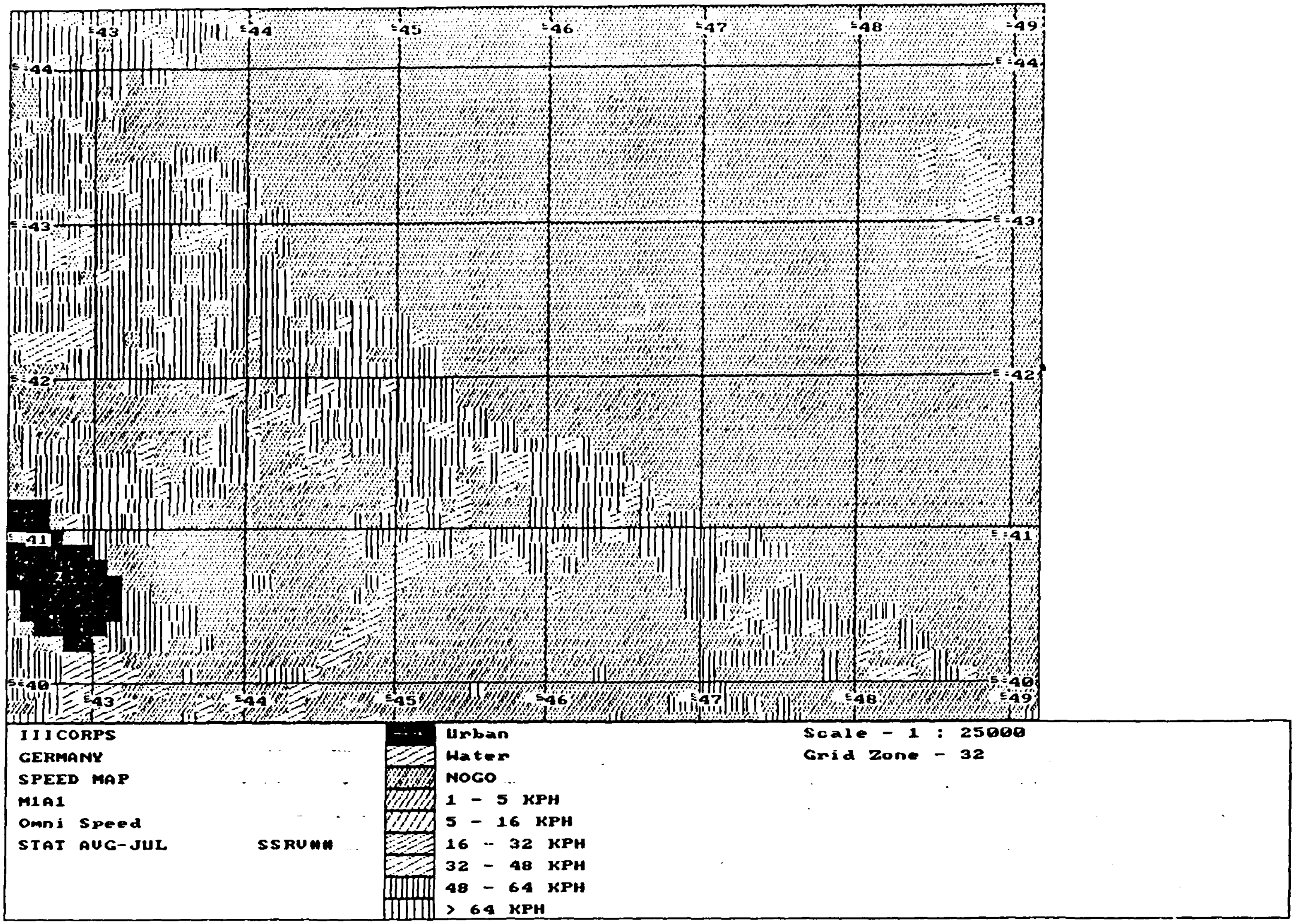
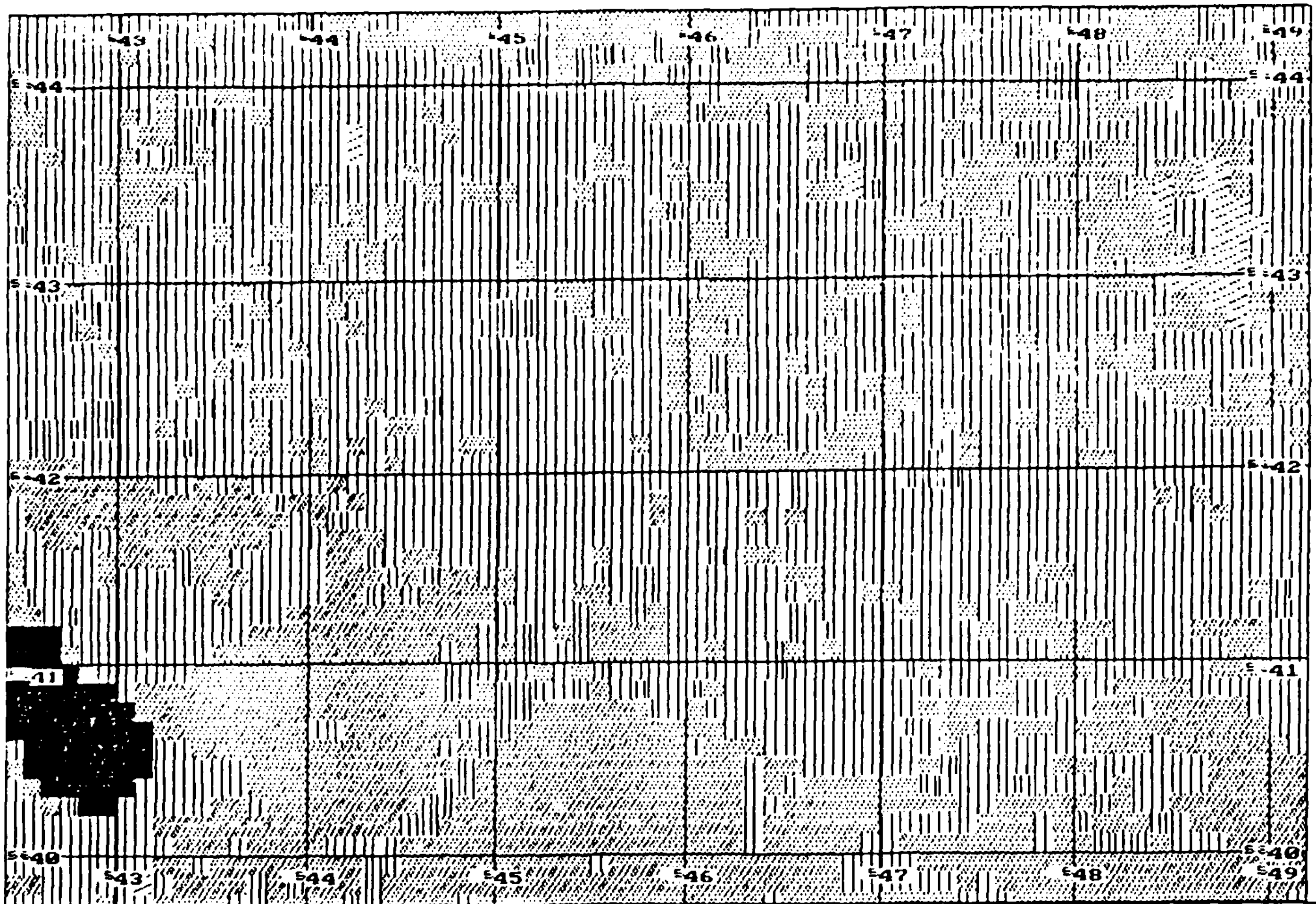


Figure D-4. M1A1, July, SSRV



IIICORPS
GERMANY
SPEED MAP
M1A1
Omni Speed
STAT AUG-FEB ###U##

Urban
Water
NOGO
1 - 5 KPH
5 - 16 KPH
16 - 32 KPH
32 - 48 KPH
48 - 64 KPH
> 64 KPH

Scale - 1 : 25000
Grid Zone - 32

Figure D-5. M1A1, February, Veg Only

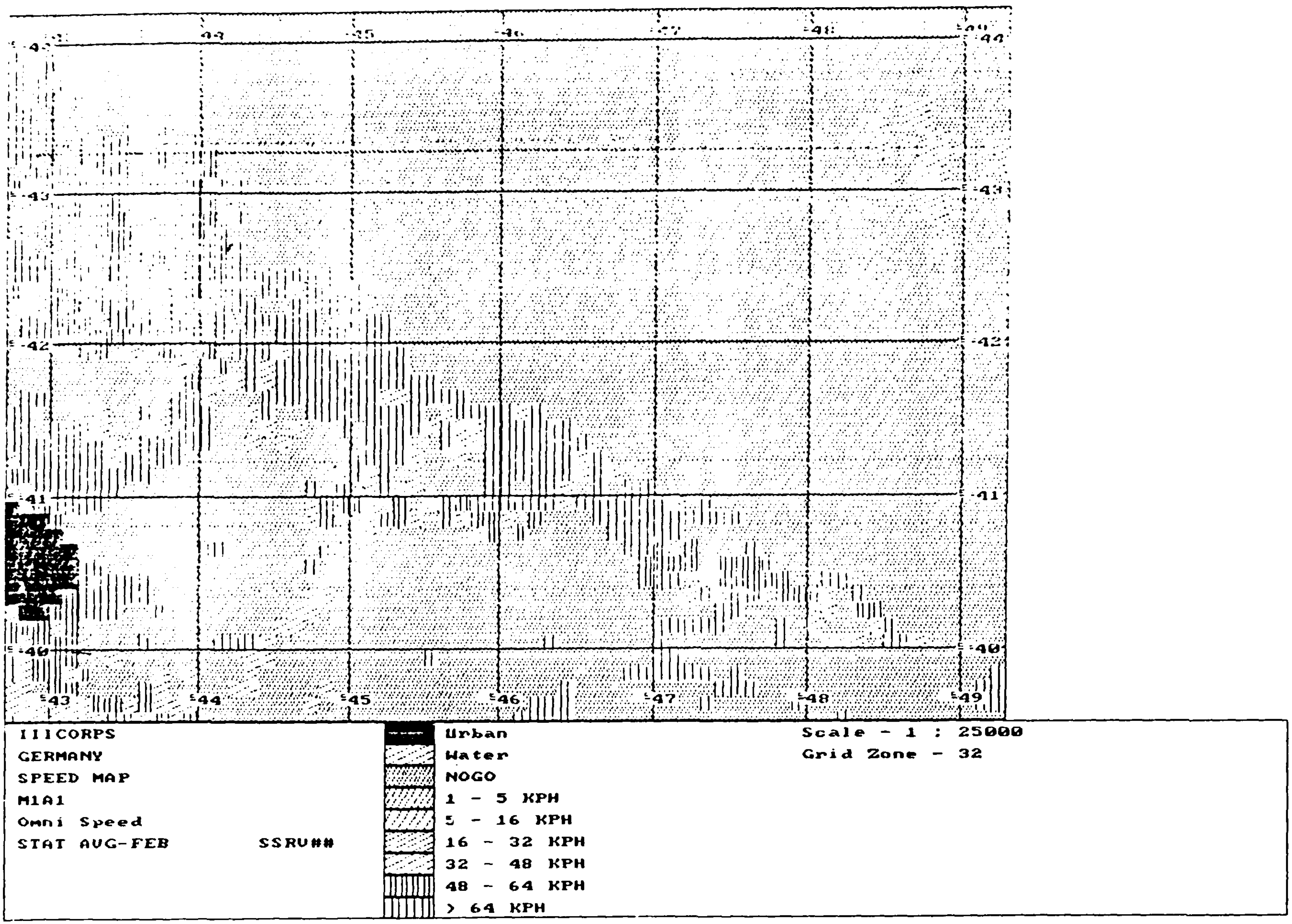


Figure D-6. M1A1, February, SSRV

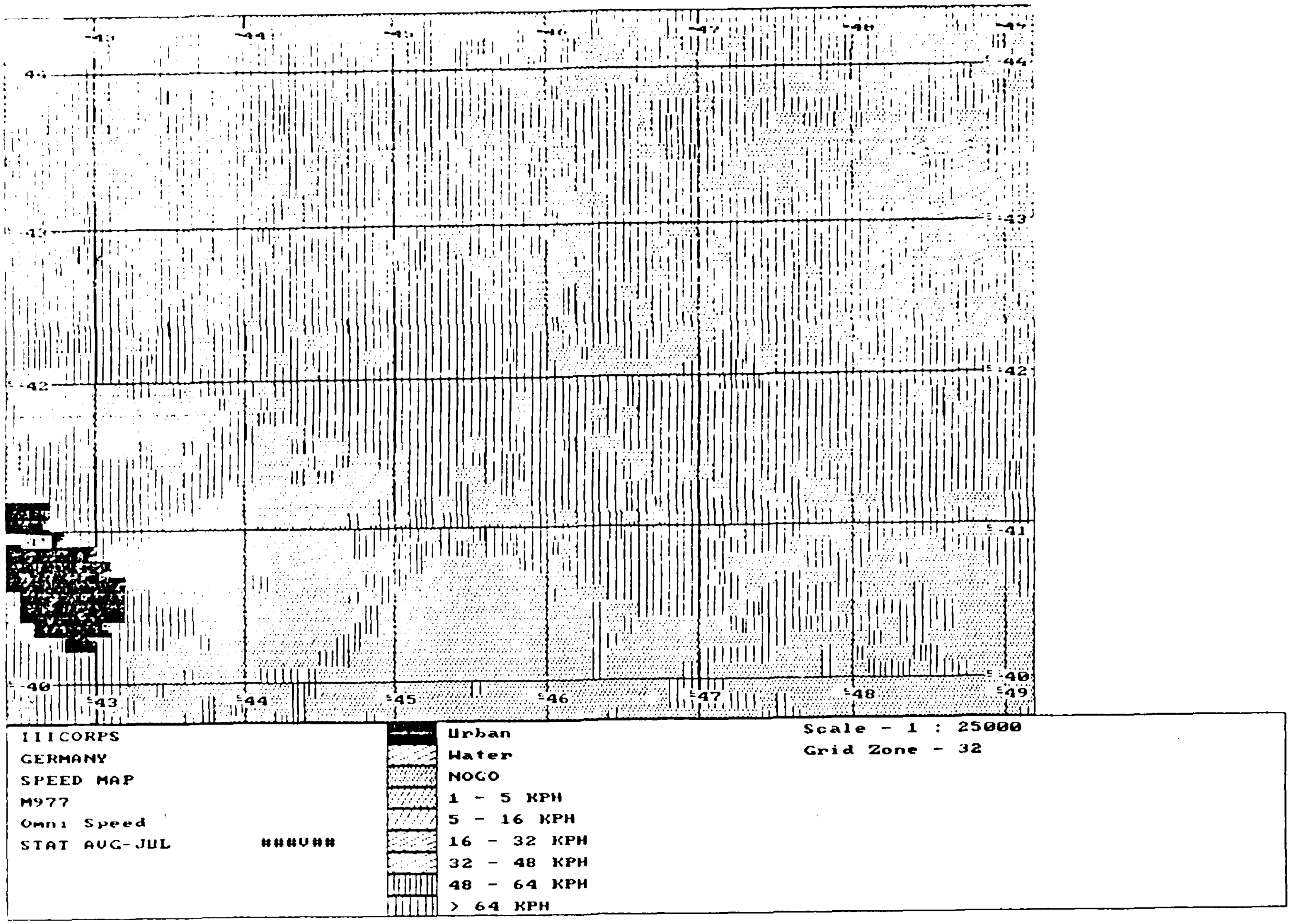


Figure D-7. M977, July, Veg Only

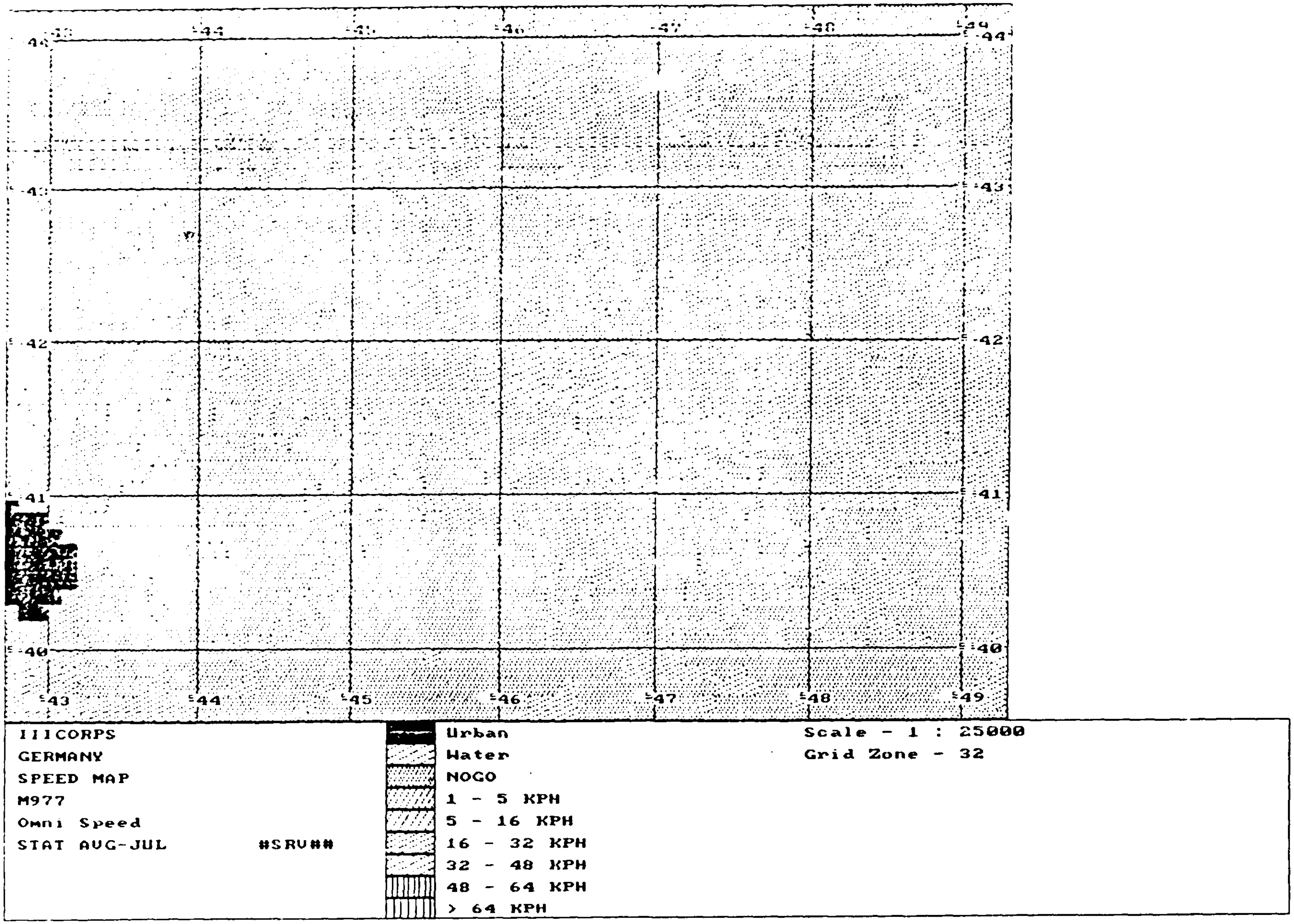


Figure D-8. M977, July, SRV

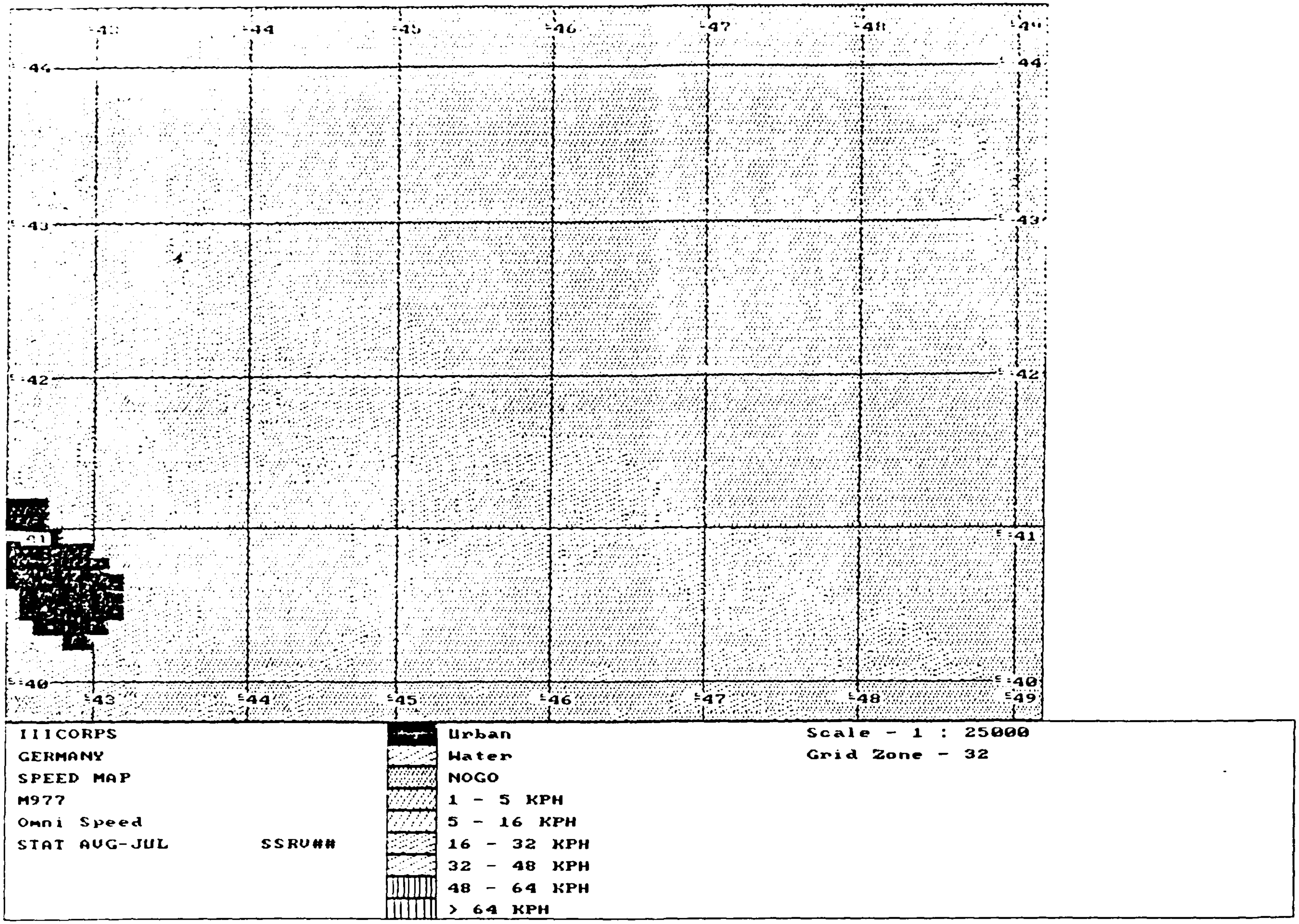


Figure D-9. M977, July, SSRV

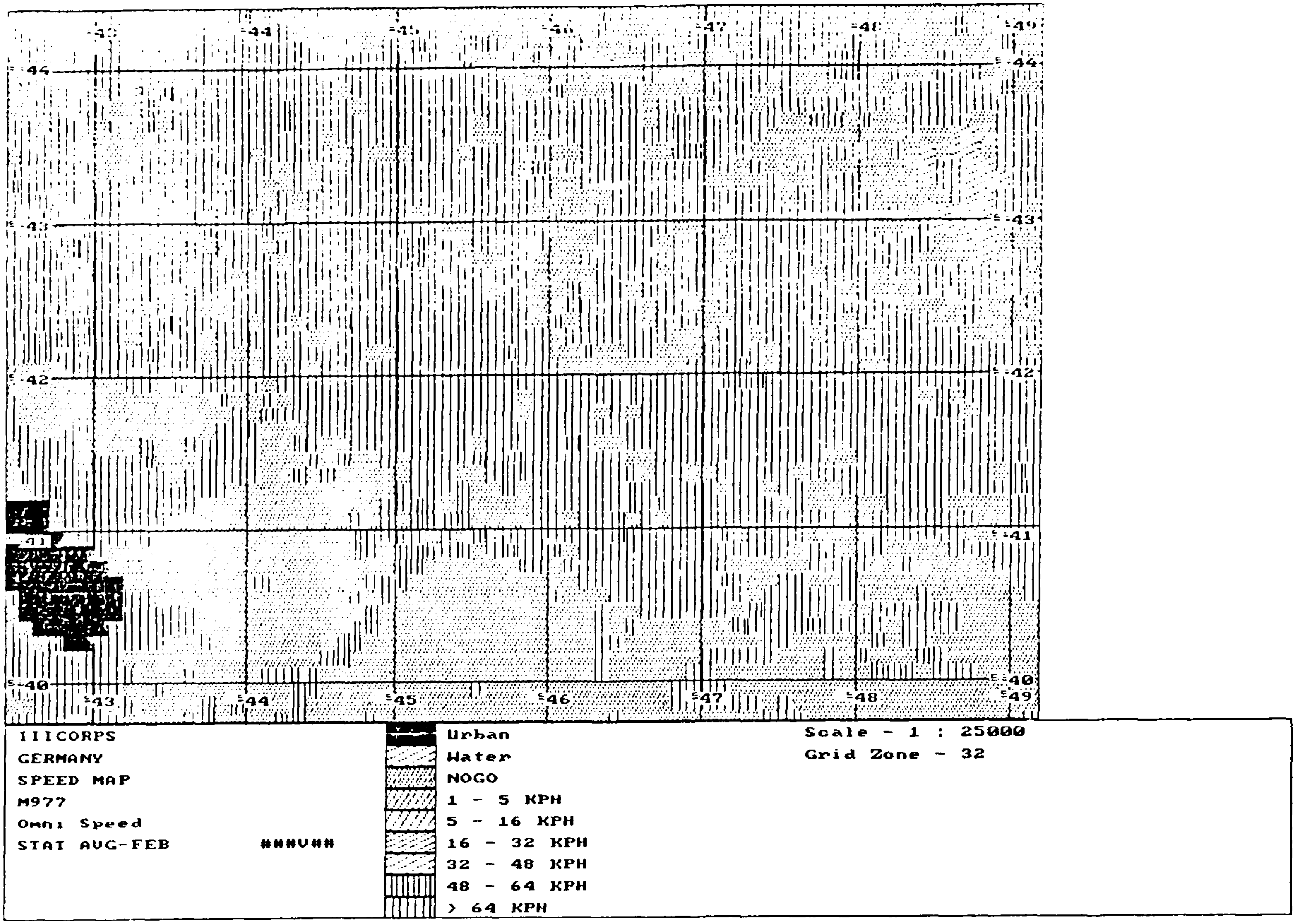


Figure D-10. M977, February, Veg Only

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Defense Technical Information Center
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